United States Department of Agriculture
Animal and Plant Health Inspection Service

ORGANISM PEST RISK ASSESSMENT:

Risks to the Continental United States Associated with Pine Shoot Beetle, *Tomicus piniperda* (Linnaeus), (Coleoptera: Scolytidae)

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Executive Summary

This pest risk assessment (PRA) was conducted at the request of the Southern Plant Board, the National Plant Board and USDA-APHIS-PPQ-PDMP. Its purpose is to address the following issues regarding *T. piniperda*:

1) What are the pathways of movement?
2) What is the predicted spread with regulations?
3) What are the economic consequences of spread?
4) What are the environmental consequences of spread?
5) What are the distinguishing characteristics of southern, northeastern, north central and western pine resources that may point toward regulatory adjustments on a regional basis?
6) What is the expected impact on species of southern pines if the movement of regulated articles is permitted from known infested areas into the southern region with and without various safeguarding measures?

This risk assessment evaluated the overall risk to the U.S. associated with *T. piniperda.* The beetle scored medium with regard to cumulative risk. It scored high with regard to habitat suitability, dispersal potential and economic impact. *Tomicus piniperda* scored low with regard to host range due to its preference for species in the genus *Pinus*. The environmental impact was scored as low for the U.S. based on the historical and biological information regarding *T. piniperda's* impact in natural forest settings. These scores indicate that *T. piniperda* could pose a potential economic threat to the U.S. Christmas tree, forestry and nursery industries.

Climate will probably not limit the distribution of *T. piniperda* in the U.S. Consequently, its projected area of colonization in the U.S. will probably depend on the distribution of pines. Pines are found throughout the U.S. with the highest concentrations in the south, west and northeast and north central states, respectively.

Regions of the U.S. were evaluated for susceptibility and associated impact from *T. piniperda*. Factors considered included: 1) host type, 2) host density and 3) potential economic impacts to the forestry, Christmas tree and nursery industries. We scored the south and west as being at greater risk from *T. piniperda* as compared to the northeast and north central U.S.

The southern U.S. has a concentrated distribution of pines that are uniformly distributed. The major planted pine species in the south is loblolly, a suitable *T. piniperda* host for both brood and shoot feeding. The estimated annual value of southern logs, pulpwood, timber and veneer is valued at over 8 billion dollars. The south is the world's largest softwood timber producer and its output is projected to increase. In addition, the south is often struck by tropical storms and hurricanes that could produce substantial brood host material for *T. piniperda*. These characteristics indicate that southern pine resources may be at substantial economic risk from *T. piniperda*.

However, there is uncertainty regarding the spread rate and degree of impact *T. piniperda* will have on southern pine resources due to interspecific competition with native bark beetles and stand vigor. Given the potential consequences of *T. piniperda* introduction, it is recommended that southern pine resources be protected by regulatory means that are precise and economically expedient until more is known regarding its ability to impact the south. Central questions that need to be addressed include: 1) can *T. piniperda* displace indigenous bark beetles, 2) will *T. piniperda* cause minimal forest damage in the southern U.S. as it does in the northeast and north central U.S. or will it become a major forest pest as observed in China and Europe and 3) how will *T. piniperda*'s biology, *e.g.* overwintering behavior and flight patterns, change as it moves into lower latitudes.

Tomicus piniperda can spread through natural or artificial means. Natural spread mechanisms include: 1) flight and 2) wind dispersal. Artificial, *i.e.* human mediated, pathways of *T. piniperda* movement include: 1) bark nuggets, 2) barked logs and lumber, 3) Christmas trees, 4) nursery stock, 5) raw pine materials for wreaths and garlands and 6) pine stumps.

Currently, *T. piniperda* appears to be spreading through: 1) natural means, *e.g.* flight, and 2) human movement of infested commodities in the regulated area, at a maximum average estimated rate of 33 miles per year. We concluded this because the beetle has generally not moved great distances, *e.g.* across one or more states, in a single year.

Tomicus piniperda will probably be able to continue naturally spreading to the east and northeast as long as host material is available regardless of regulation. Its natural spread to the south may be mitigated by interspecific competition from native bark beetles and good stand management. Its natural spread west may be mitigated by a lack of concentrated host material in the plains states and the absence of aggregation pheromones.

The effect of deregulation on the rate of *T. piniperda* spread throughout the U.S. will depend on a variety of factors including: 1) *T. piniperda* commodity infestation rate, 2) commodity shipping distance, 3) method of commodity disposal, *e.g.* chipping, 4) volume of commodity imported and 5) time of importation. There is a large degree of variability with regard to the risk of *T. piniperda* introduction by pathway, regional commodity production and shipping intensity. For example, deregulation of the Christmas tree or nursery pathways could facilitate the movement of *T. piniperda* throughout the U.S. in a single year. However, the likelihood of introduction via the Christmas tree pathway maybe low because pest management practices can limit *T. piniperda* populations in plantations. Deregulation of the pulpwood pathway could increase the southern rate of spread to 60 to 75 miles per year due to mill pulpwood purchase radii. Due to this variability, we suggest that the rate of human mediated spread in the event of *T. piniperda* deregulation be estimated with specific risk assessments for each region and pathway.

The fact that *T. piniperda* has not generally moved across one or more states in a given year indicates that the regulatory program is preventing its long distance movement via artificial means, *e.g.* pine nursery tree or timber shipments. Therefore the regulatory program should be maintained until more is known regarding the impact of *T. piniperda* on other regions of the country. However, consideration could be given to exploring the practicality of adjusting the regulatory program: 1) to reflect regional differences in *T. piniperda* flight period, brood biology and overwintering habits and 2) to reflect the variation in risk among regions with regard to different pathways. These steps could: 1) provide more efficacious protection due to a targeted and expeditious use of resources and 2) reduce economic costs associated with quarantines. It is acknowledged that while giving relief in various regards to different regions of the country, these adjustments could increase the complexity of the *T. piniperda* regulatory program nationwide and pose new challenges. Suggestions on how to improve the precision of the regulatory program are provided.

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I. Introduction

Tomicus piniperda, the pine shoot beetle, is a member of the economically important bark beetle family Scolytidae (Borror *et al*., 1989; CABI, 2004). The principal hosts of *T. piniperda* are pines (CABI, 2004). It will attack the stem of weakened trees during breeding and the shoots of weakened or healthy trees during sexual maturation (Haack and Kucera, 1993). In natural settings the beetle acts a decomposer but in plantation settings it can cause substantial economic damage if populations reach high levels (Czokajlo *et al*., 1997; Långström and Hellqvist, 1991; Morgan *et al*., 2004). *Tomicus piniperda* is considered a major forest pest in Europe and China (CABI, 2004; Ye, 1991). *Tomicus piniperda* is also a trade concern because it will readily move in dunnage and wood packing materials (PIN, 2005).

In 1992, *T. piniperda* was detected in a Christmas tree plantation near Cleveland, Ohio (Haack and Kucera, 1993). Since then it has been detected in 14 states and resulted in 473 regulated U.S. counties due to natural spread, human movement of infested commodities in the regulated area and increased surveys (Haack and Poland, 2001; Heilman *et al*., 2005; NAPIS, 2005; USDA-APHIS, 2005a, 2005b).

The presence of *T. piniperda* in the U.S. has resulted in quarantines on the movement of potentially infested articles (CFR, 2003, 2005). Regulated pine articles include: 1) Christmas trees, 2) nursery stock, 3) logs with bark, 4) lumber with bark, 5) stumps and 6) bark nuggets.

The purpose of this pest risk assessment was to evaluate the risks posed by *T. piniperda* to the U.S. We characterized the overall risk associated with *T. piniperda* using a pest risk assessment template developed by APHIS-PPQ. Topic areas addressing specific issues were then added as necessary. In addition, we identified areas of uncertainty and made recommendations regarding regulations and future research needs for *T. piniperda*. This information can be used to facilitate the implementation of regulatory practices regarding the beetle with the goal of protecting U.S. pine resources in an efficacious and economically expedient manner.

II. Life History

A. Biology and Ecology

Tomicus piniperda is univoltine and mainly attacks pine trees (CABI, 2004; Poland *et al*., 2003). Warm temperatures induce emergence from overwintering and subsequent flight of adults in the early spring. Studies indicate that *T. piniperda* can fly at least 2 km (l.2 miles) upon emergence from overwintering in search of suitable brood host material (Barak *et al.*, 2000). In North America the flight peak occurs between February and April depending on the latitude (Poland *et al*., 2002). Maximum daily temperatures above 12°C can initiate *T. piniperda* flight (Haack and Lawrence, 1997; Poland *et al*., 2002).

Beetles seek out stressed or recently felled timber based on the presence of semiochemicals, *e.g.* alpha pinene, produced by the tree (Poland *et al*., 2003, 2004). The monogamous females mate, construct egg galleries and oviposit in the host tree (CABI, 2004). The formation of sister broods can occur when females oviposit in multiple trees (Poland *et al*., 2002). A portion of the *T. piniperda* population carries a fungal symbiont, *e.g. Leptographium wingfieldii*, which may assist the beetles in overcoming host defenses by reducing the vigor of the tree (CABI, 2004; Lieutier *et al*., 1989).

The larvae hatch, feed on phloem, pupate and emerge from the host tree between May and June in the U.S. depending on latitude (Haack and Kucera, 1993; Haack *et al*., 1998; Poland *et al*., 2002). The newly emerged adults fly short distances, *e.g.* 30 m, and attack the shoots of healthy or weakened host trees (Ciesla, 2001; Morgan *et al*., 2004; Ye and Li, 1994). *Tomicus piniperda* prefers to attack shoots in the upper portion of the host trees (Ciesla, 2001). Shoot feeding by the newly emerged adults usually occurs between May and October and is required for sexual maturation (Ciesla, 2001). The number of shoots attacked is strongly correlated with the volume of brood material, *e.g.* weakened or felled trees, in the vicinity (Morgan *et al*., 2004). Adult *T. piniperda* shoot feeding consists of tunneling into the center and hollowing out the shoot (Ciesla, 2001). This feeding method often causes the shoot to weaken, desiccate and break off (Figure 1). One adult beetle may attack up to 6 shoots during the maturation feeding phase (Haack and Kucera, 1993).

When temperatures drop in the fall, *T. piniperda* will overwinter. In warmer areas, overwintering occurs in the shoot. In colder areas, the adult will move to the base of its host tree or a nearby pine tree, tunnel into the bark and overwinter (Ciesla, 2001; Haack and Kucera, 1993; Ye *et al*., 2002).

Figure 1. Shoot damaged by *T. piniperda* (Steve Passoa, USDA APHIS PPQ, www.forestryimages.org)

III. Geographic Distribution

A. Global Distribution

Tomicus piniperda is present in Northern Africa, Canada, China, Europe, Japan, North Korea, Russia and the United States (CABI, 2004) (Figure 2).

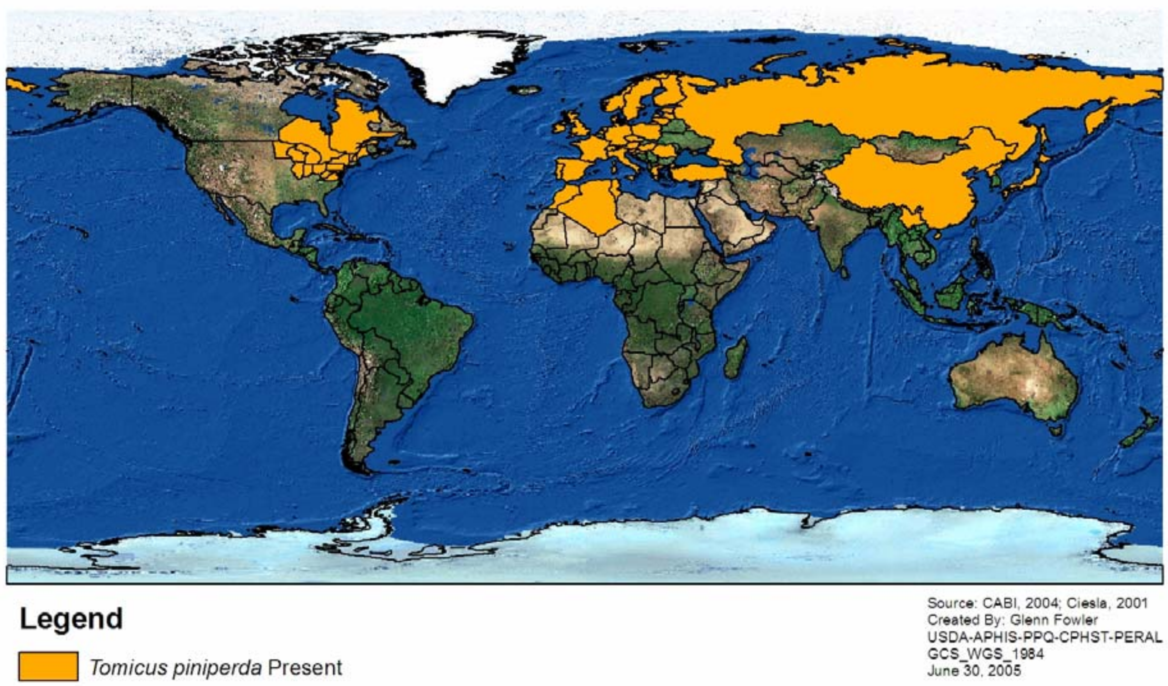

Figure 2. Geographic distribution of *T. piniperda.*

B. Current Distribution in the U.S. and History of Introduction

Tomicus piniperda was first detected in the U.S. near Cleveland Ohio in 1992 (Haack and Kucera, 1993). As of July 13, 2005 it has been detected in 14 states, resulting in 473 regulated counties (Haack and Poland, 2001; Heilman *et al*., 2005; NAPIS, 2005; USDA-APHIS, 2005a, 2005b) (Figure 3).

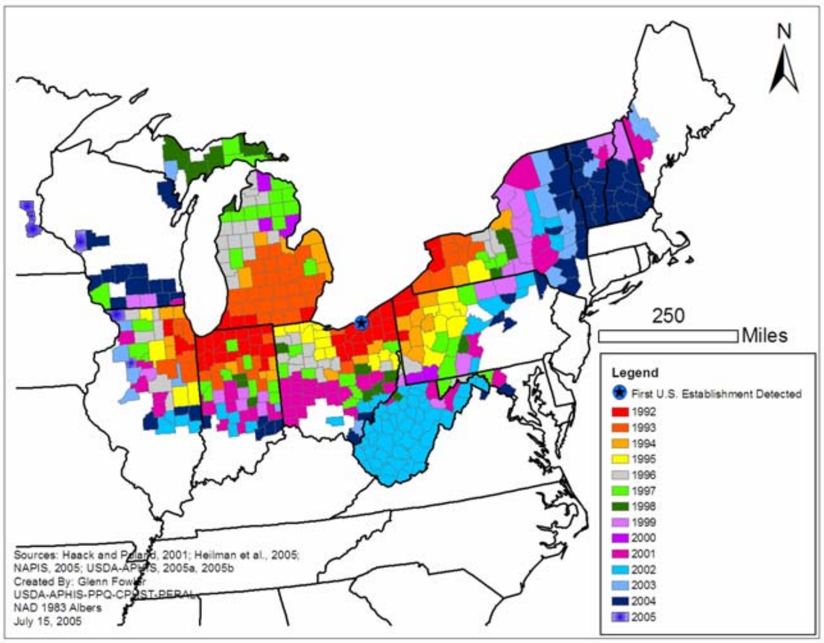

Figure 3. U.S. quarantine counties added by year for *T. piniperda*.

IV. Consequences of Introduction

A. Risk Element 1. Habitat Suitability

Rating	Numerical Score	Explanation
High	**3**	**Attacks and survives on hosts in 4 or more plant hardiness zones**
Medium	2	Attacks and survives on hosts in 2 or 3 plant hardiness zones
Low	1	Attacks and survives on hosts in at most a single plant hardiness zone

Rank: High

A degree day model for *T. piniperda* based on the work of Ye (1994) was simulated using the NAPPFAST system. The model demonstrated that *T. piniperda* could complete its development throughout the U.S. Consequently, host distribution will probably be the factor that limits its distribution. The distribution of pine hosts in the U.S. indicates that

T. piniperda could establish in USDA plant hardiness zones 3 through 9 (Figures 4, 5 and 6). This confers *T. piniperda* a rank of High with regard to habitat suitability in the U.S. (USDA-ARS, 1990).

In northeastern and north central states, the pine host distribution includes USDA plant hardiness zones 3 through 6 (Figures 4, 5 and 6) (USDA-ARS, 1990). In the southern states, the pine host distribution includes USDA plant hardiness zones 6 through 9. In the western states, the pine host distribution includes USDA plant hardiness zones 3 through 8. This confers *T. piniperda* a rank of High with regard to habitat suitability in each of these regions.

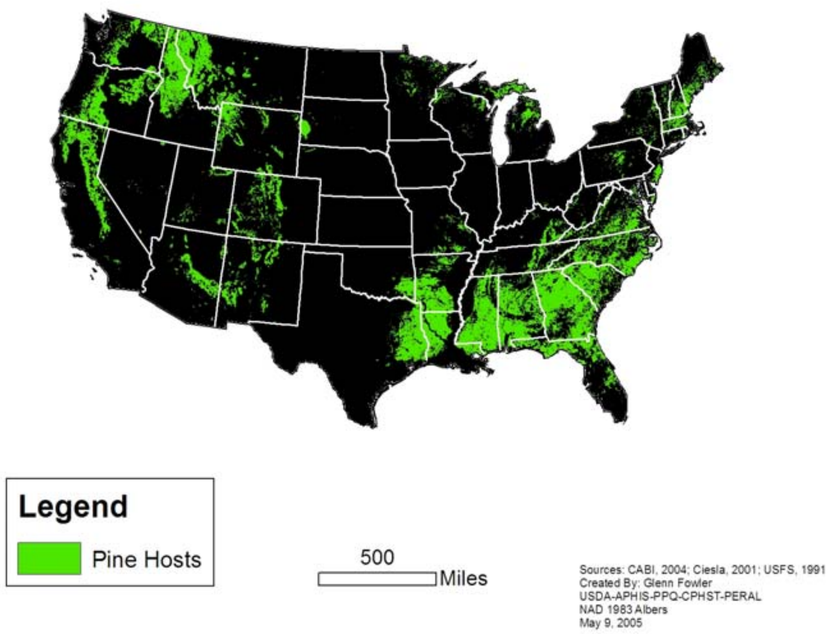

Figure 4. U.S. *T. piniperda* pine hosts distribution on timberland (CABI, 2004; Ciesla, 2001; USDA-USFS, 1991).

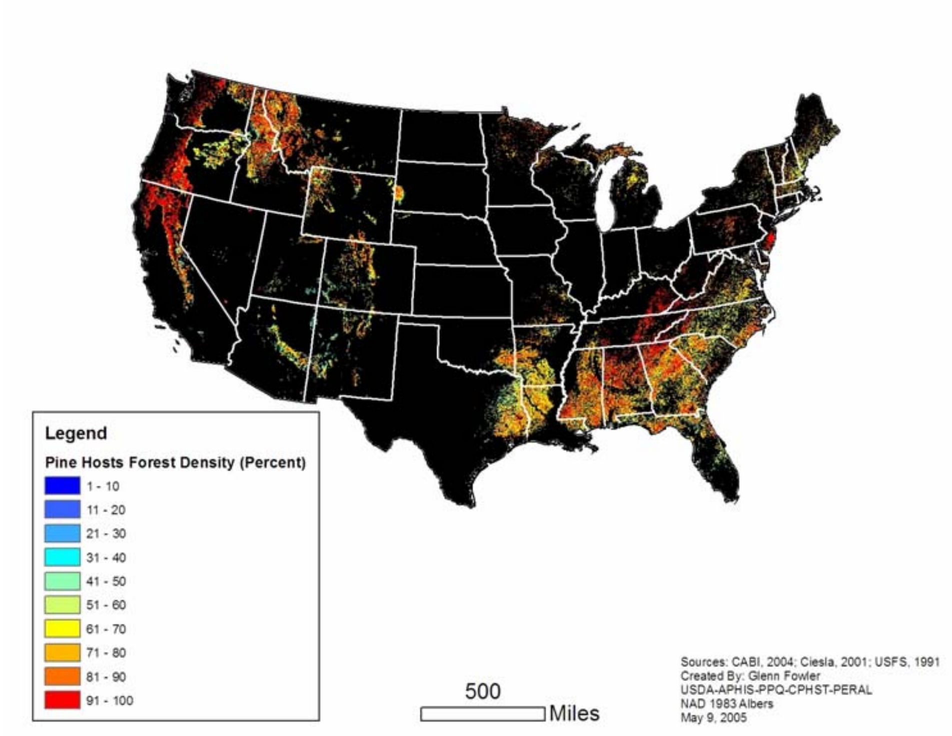

Figure 5. U.S. *T. piniperda* pine hosts density (CABI, 2004; Ciesla, 2001; USDA-USFS, 1991). Pine hosts density is reported in percent forest cover in timberland (USDA-USFS, 1991).

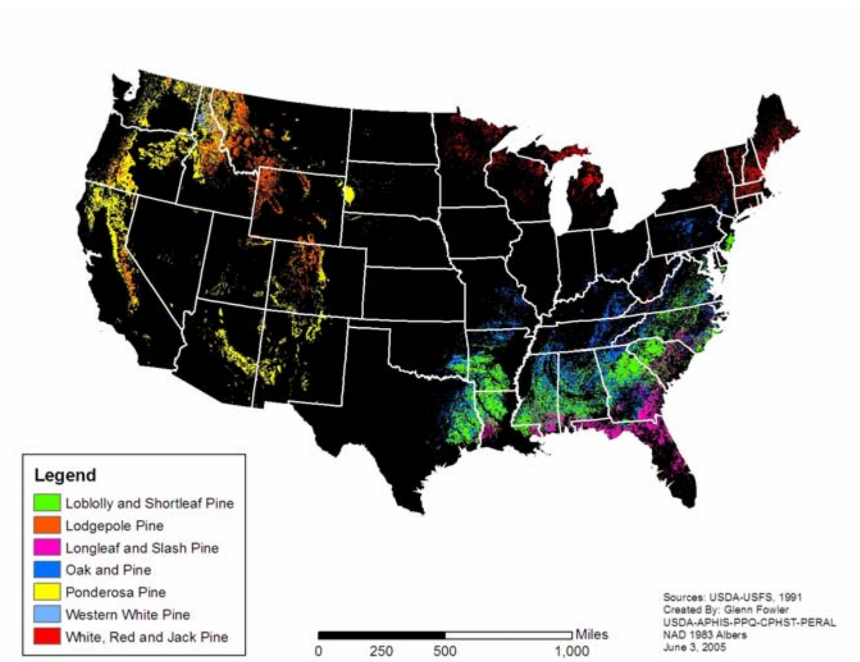

Figure 6. Major pine forest types in the continental U.S. (USDA-USFS, 1991).

B. Risk Element 2: Host Range

Rating	Numerical Score	Explanation
High	3	Insect attacks multiple species within multiple host families
Medium	2	Insect attacks multiple species within a single host family
Low	**1**	**Insect attacks only a single species or multiple species within a single genus**

Rank: Low

Pines are the principal hosts of *T. piniperda*, and it can complete its lifecycle on multiple species within this genus (CABI, 2004; Ciesla, 2001). The beetle has also been recorded occasionally attacking other conifers, *e.g.* spruce, Douglas fir, fir (*Abies*) and larch (Browne 1968; Grüne, 1979; Haack pers. comm., 2005; Lutyk, 1984). Attacks on these trees are rare and they are not considered important hosts (CABI, 2004). Based on this information we consider pines to be the only viable hosts with regard to risk scoring. We score *T. piniperda* a rank of Low with regard to host range.

C. Risk Element 3: Dispersal Potential

	Dispersal Considerations	**Source**
X	Consistent and prolific reproduction	Ye, 1991
	Rapid growth to reproductive maturity	
X	Wide range of hosts	CABI, 2004
X	Tolerant to temperature extremes	CABI, 2004
	Phoresy, *i.e.* dispersal by utilizing another organism	
	Ability to utilize different host during different life stages	
	Social behavior	
	Migratory behavior/swarming	
	Alteration of generations/parthenogenesis/phase polymorphism	
X	Can reside within host	CABI, 2004
X	Diapause/overwintering	CABI, 2004
X	Stress tolerance, including ability to resist insecticides and/or adverse weather conditions	CABI, 2004
	Lack of natural control agents	
X	Natural dispersal	Barak *et al.*, 2000
X	Wind dispersal	Haack and Poland, 2000
	Water dispersal	
	Machinery dispersal	
	Animal dispersal	
X	Human dispersal	USDA-APHIS, 1993

Rating	**Numerical score**	**Explanation**
High	**3**	**Insect has high reproductive potential (*e.g.*, prolific egg production, high survival rate, reproduction by parthenogenesis, bimodal population behavior) AND highly mobile life stages (*i.e.*, capable of moving long distances aided by wind, water or vectors)**
Medium	2	Insect has either high reproductive potential OR highly mobile life stages
Low	1	Insect has neither high reproductive potential nor highly mobile life stages

Rank: High

Tomicus piniperda can fly at least 2 km (1.2 miles) in search of brood host material upon emergence after overwintering (Barak *et al*., 2000). Wind may also enhance long distance flight dispersal (Haack and Poland, 2000). It can also be moved by human transport mechanisms, *e.g.* timber logs, nursery stock and dunnage (USDA-APHIS, 1993). Since the initial detection in 1992, *T. piniperda* has expanded it range into 14 states, resulting in 473 regulated counties (Haack and Poland, 2001; Heilman *et al*., 2005; NAPIS, 2005; USDA-APHIS, 2005a, 2005b) (Figure 3). It should be noted that the entire state of West Virginia elected to become quarantined in 2001 (CFR, 2001; Haack and Poland, 2001). Also, all counties in New Hampshire and Vermont became quarantined in 2004 (USDA-APHIS, 2005a).

Tomicus piniperda also demonstrates high reproductive potential (Sauvard, 1993). For example, up to 300 egg galleries per m^2 were observed in recently felled pines in Sweden (Långström, 1986). An average of 76 eggs can be deposited per egg gallery (Ye, 1991). Also, despite the fact that *T. piniperda* is univoltine, multiple sister broods can occur in a year (Sauvard, 1993).

Given the reproductive potential and historical documented movement since introduction, *T. piniperda* is ranked High with regard to dispersal potential.

The southern movement of *T. piniperda* may be slowed due to interspecific competition with indigenous bark beetles, *i.e.* southern pine beetle (*Dendroctonus frontalis*), black turpentine beetle (*Dendroctonus terebans*) and Ips beetles (*Ips avulsus, I. calligraphus and I. grandicollis*), for brood host material (CABI, 2004; Haack pers. comm., 2005) (Figure 7). These indigenous beetles form a guild that can coexist on the same pine host via spatial partitioning of resources (CABI, 2004). In order for *T. piniperda* to successfully establish in the southern U.S. it will need to displace one or more of these species temporally and/or spatially.

Interspecific competition with native bark beetles will probably affect *T. piniperda* in 2 ways. First, it will reduce the quantity of brood host material available (Haack pers. comm., 2005). Secondly, there may be competition for the same host material. This type of competition could have both positive and negative effects for *T. piniperda* on host colonization (Amezaga and Rodríguez, 1998; Ye and Ding, 1999). The positive effect is that attacks by multiple species can facilitate overcoming tree resistance. This would be especially beneficial to *T. piniperda* because, unlike many other bark beetles *e.g. D. frontalis,* it does not have a definitive ability to use aggregation pheromones to attack hosts (CABI, 2004; Poland *et al*., 2004). The negative effects of interspecific competition for the same resource include reduced fecundity, female survival and larval density (Amezaga and Rodríguez, 1998; Ye and Ding, 1999).

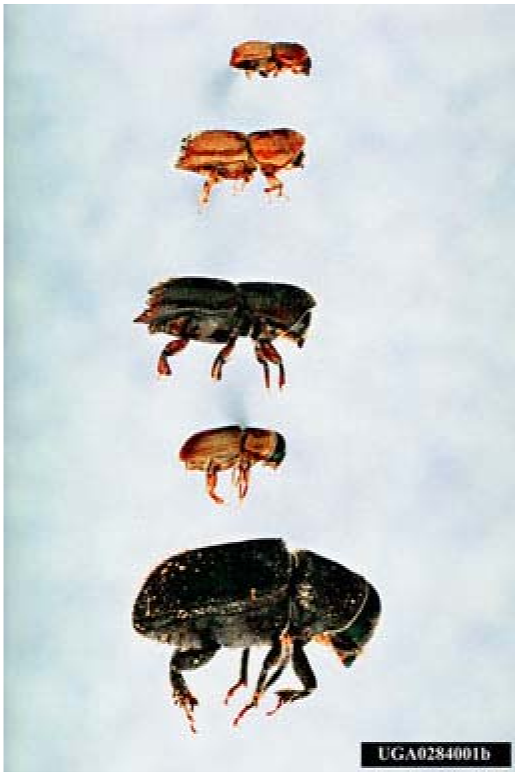

Figure 7. Specimens of the major pine infesting bark beetle guild present in the southern U.S. (Gerald J. Lenhard, www.forestryimages.org). From top to bottom: small southern pine engraver (*Ips avulses*), southern pine engraver (*I. grandicollis*), six-spined engraver (*I. calligraphus*), southern pine beetle (*Dendroctonus frontalis*) and black turpentine beetle (*D. terebans*).

Table 1. State distribution of *T. piniperda* and likely interspecific bark beetle competitors (CABI, 2004; NAPIS, 2005).

Species	State Distribution
Dendroctonus frontalis	Alabama, Arizona, Arkansas, California, Delaware, District of Colombia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, West Virginia
Dendroctonus terebans	Arkansas, Florida, Georgia, Idaho, Louisiana, Massachusetts, Mississippi, North Carolina, Oklahoma, Texas
Ips avulsus	Florida, Georgia, Louisiana, Oklahoma, Texas
Ips calligraphus	Alabama, Arizona, Arkansas, California, Colorado, Connecticut, Delaware, Florida, Georgia, Illinois, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Montana, Nebraska, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Utah, Virginia, West Virginia, Wisconsin, Wyoming
Ips grandicollis	Alabama, Arkansas, Connecticut, Florida, Georgia, Illinois, Indiana, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, West Virginia, Wisconsin
Tomicus piniperda	Illinois, Indiana, Maine, Maryland, Michigan, Minnesota, New Hampshire, New York, Ohio, Pennsylvania, Vermont, West Virginia, Virginia (1 county), Wisconsin

Predictive modeling using the NAPPFAST system indicated that *T. piniperda* is approaching areas where interspecific competition should increase due to climates conducive for the survival of southern pine beetle (*D. frontalis*) (Figure 8). We placed emphasis on interspecific competition with *D. frontalis* because: 1) it is the primary cause of insect induced economic damage in the southern states, 2) it has the potential for explosive population outbreaks due to its rapid multivoltine life cycle, 3) it will aggressively attack pine hosts en masse, 4) large outbreaks of the other indigenous bark beetles are less frequent in the south and 5) it will fly throughout the year (Borror *et al*., 1989; CABI, 2004; Thompson and Moser, 1986). These characteristics indicate that *D. frontalis* will probably be the strongest competitor with *T. piniperda* for resources. The effect of interspecific competition will probably be most applicable in states like Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina and Texas where the temperatures rarely drop to levels that are lethal to *D. frontalis* and outbreaks are more frequent (USDA-USFS, 2003) (Figure 8).

The ability for *T. piniperda* to disperse in the southern states should be greatest during the late winter months, *e.g*. February, because it will probably initiate flight before most of the indigenous bark beetles (*e.g.* flight temperature = 12°C for *T. piniperda* and 15°C for *I. grandicollis*) (CABI, 2004; Hack and Lawrence, 1997; Haack pers. comm., 2005; Poland *et al*., 2002). Consequently, it would suffer less interspecific competition for brood host material during this period (Haack pers. comm., 2005). This has been observed in studies on interspecific competition between *T. piniperda* and other bark beetle species *e.g. Ips pini, Orthotomicus erosus* and *T. minor* (Amezaga and Rodríguez, 1998; Haack and Lawrence, 1995; Ye and Ding, 1999). These studies indicated that *T. piniperda* had a competitive advantage when it colonized the hosts first. As interspecific competition later increased, there were decreases in *T. piniperda* fecundity and larval density (Ye and Ding, 1999).

A notable exception to the later flight time by southern bark beetles as compared to *T. piniperda* is *D. frontalis*. Research by Thompson and Moser (1986) in Louisiana indicated that the optimal flight temperature for *D. frontalis* is 27°C but the minimum flight temperature was 6.7°C during sunny days. Also, *D. frontalis* does not hibernate like other bark beetles and will fly throughout the year (Thompson and Moser, 1986). Consequently, the effect of interspecific competition from *D. frontalis* on *T. piniperda* brood host colonization may be more substantial than is hypothesized here.

Tomicus piniperda is univoltine and should be at a competitive disadvantage for new brood host material once the other multivoltine beetles initiate flight (Kennedy and McCullough, 2002). Also, the indigenous bark beetles, *e.g. D. frontalis*, use aggregation pheromones to overcome tree defenses while *T. piniperda* apparently lacks this capability (CABI, 2004; Haack and Kucera, 1993; Kennedy and McCullough, 2002). Consequently, the indigenous bark beetles should be able to colonize pine hosts with greater efficacy than *T. piniperda* during most of the year (Kennedy and McCullough, 2002). Lastly, *T. piniperda* must feed on shoots in order to complete sexual maturation (Haack and Kucera, 1993). The frequency of *T. piniperda* shoot attacks has been shown to depend on the availability of brood material in late winter and early spring (Morgan *et al*., 2004). The quantity of brood material may be compromised later in the season due to the interspecific competition factors mentioned above. The combination of these interspecific competitive factors may reduce the rate and degree of *T. piniperda* establishment in the southern states as compared to the northeast and north central U.S. (Haack pers. comm., 2005).

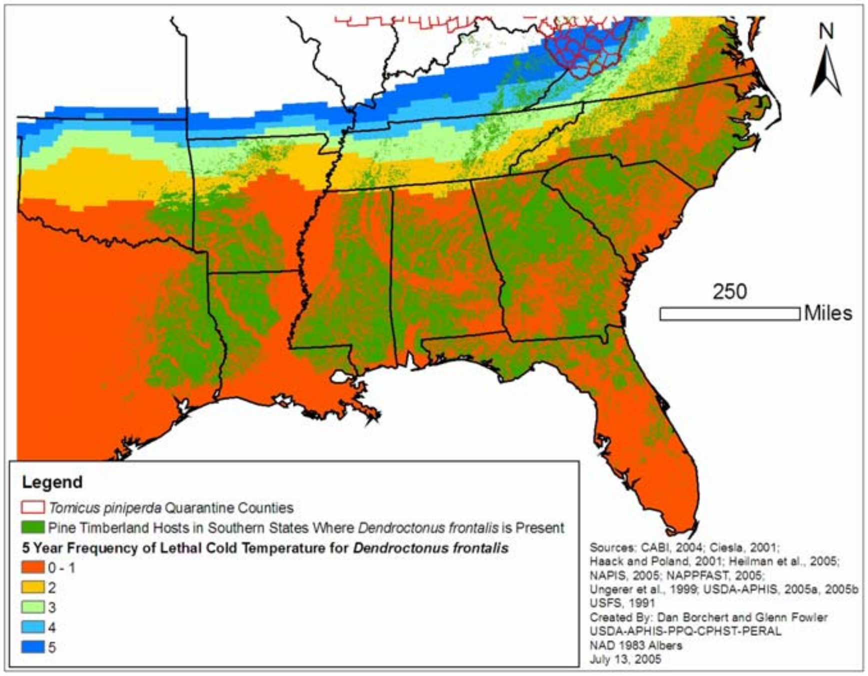

Figure 8. Location of *T. piniperda* quarantine counties in relation to major southern pine stands and areas reaching the lethal temperature limit (-16°C) for *D. frontalis* 0 to 5 of the past 10 years (1995-2004)

D. Risk Element 4: Economic Impact

Impact Categories:

1. Reduced commodity yield (*e.g.*, feeding, disease vector).
2. Lower commodity value (*e.g.*, by increasing costs of production, lowering the market price, or a combination); or if not an agricultural insect, by increasing costs of control.
3. Loss of markets (foreign or domestic) due to presence of a new quarantine pest.

Rating	Numerical score	Explanation
High	**3**	**Insect causes all three of the above impacts, or causes any one impact over a wide range of economic plants, plant products or animals (over 5 types)**
Medium	2	Insect causes any two of the above impacts, or causes any one impact to 3 or 4 types of economic plants, plant products, or animals
Low	1	Insect causes any one of the above impacts to 1 or 2 types of economic plants, plant products, or animals
Nil	0	Insect causes none of the above impacts

Rank: High

Tomicus piniperda damages pine trees by: 1) feeding on the shoots and 2) attacking the stems (Ye, 1996). This damage can cause reductions in pine yield, quality and a loss of markets due to quarantines (CABI, 2004; CFR, 2003, 2005). *Tomicus piniperda* impacts over 5 types of economic pine commodity including: 1) lumber with bark, 2) logs with bark, 3) Christmas trees, 4) nursery stock, 5) bark nuggets and 6) stumps (CFR, 2005). These characteristics confer *T. piniperda* a rank of High with regard to economic impact in the U.S. pine producing states.

Tomicus piniperda shoot feeding reduces growth rates which could pose an economic threat to the U.S. softwood timber industry (Tables 6, 7, 8 and 9). In Europe, this type of damage is the largest economic problem associated with *T. piniperda* (CABI, 2004; Långström and Hellqvist, 1991). In a 2 year Swedish study on Scots pines near a timber yard infested with *T. piniperda*, trees lost up to 50% of their foliage, 60% radial growth, 1.5 meters in height growth and 70% of their volume growth (Långström and Hellqvist, 1991). Damage associated with *T. piniperda* decreased with increasing distance from the timber yard with volume growth losses ranging from 40% to 10%.

Shoot feeding can also reduce the aesthetic appearance and commodity value of pine Christmas and nursery trees (OHDNR, 2005) (Figure 9). A single beetle can destroy up to 6 shoots (Haack and Kucera, 1993). In unmanaged Christmas tree stands, between 28%

and 67% of the trees have exhibited shoot feeding damage from *T. piniperda* (McCullough and Sadof, 1998). However, in properly managed plantations, *T. piniperda* populations can be effectively suppressed and associated damage is minimal, *e.g.* 0% to 4% of the trees exhibiting shoot feeding damage (Haack and Poland, 2001; McCullough and Sadof, 1998).

Christmas trees are grown and shipped throughout the U.S. with annual sales valued at nearly 400 million dollars (Figure 10; Tables 2, 3 and 4) (Helmsing, 2004; Koelling *et al*., 1992; UIUC, 2005). Annual pine Christmas tree sales are estimated at nearly 110 million dollars (Helmsing, 2004; Michigan Ag Connection, 2005; Mintum pers. comm., 2005; Olsen pers. comm., 2005; USDA-ERS, 1990; USDA-NASS, 2002). In addition to the potential aesthetic damage, *Tomicus piniperda* could pose a risk to the Christmas tree industry because: 1) 3 of the top 7 selling Christmas trees are potential pine hosts, *i.e.* Scots, Virginia and white pine (UIUC, 2005) and 2) Christmas tree farms are suitable reservoirs for the beetle due to the presence of brood, shoot feeding and overwintering host material, *i.e.* stumps and live trees (Haack and Poland, 2001).

Shoot feeding damage associated with *T. piniperda* could also pose an economic threat to the nursery industry where pines are used as landscape plants and shipped interstate (Monrovia Nursery, 2005). In a USDA 17 state nursery industry survey, conducted in 2003, the annual sales of coniferous evergreens were valued at 443 million dollars (Figure 11, Table 5) (USDA-NASS, 2004).

Shoot feeding can also weaken tree defenses leading to an increased likelihood of subsequent stem attack and mortality (Lieutier *et al*., 2003; Ye, 1991). This occurred in China where large scale mortality in pine plantations due to *T. piniperda* was observed (Ye, 1991, 1992). Studies indicate that if greater than 60% of the shoots are damaged by *T. piniperda*, then tree mortality will occur due to subsequent stem attack (Czokajlo *et al*., 1997; Lieutier *et al*., 2003).

Figure 9. *Tomicus piniperda* shoot damage (Steve Passoa, USDA APHIS PPQ, www.forestryimages.org).

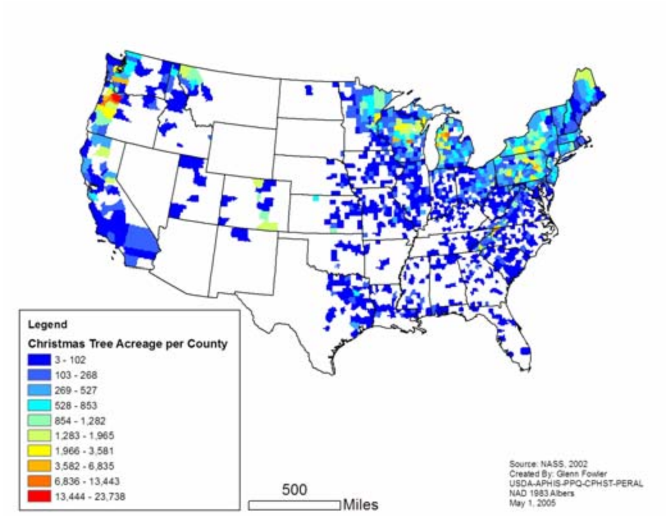

Figure 10. U.S. Christmas tree acreage.

Table 2. Annual U.S. Christmas tree production in the northeastern and north central U.S. (Helmsing, 2004; Michigan Ag Connection, 2005; Olsen pers. comm., 2005; USDA-ERS, 1990; USDA-NASS, 2002).

State	Sales	Proportion of Trees Sold that are Pines	Estimated Annual Pine Christmas Tree Sales
Connecticut	3,407,000	0.10	340,700
Delaware	401,000	0.41	164,410
Iowa	1,424,000	0.95	1,352,800
Illinois	7,633,000	0.89	6,793,370
Indiana	2,775,000	0.83	2,303,250
Massachusetts	1,800,000	0.16	288,000
Maryland	2,313,000	0.75	1,734,750
Maine	2,293,000	0.10	229,300
Michigan	30,411,000	0.21	6,386,310
Minnesota	11,855,000	NA	NA
Missouri	1,843,000	0.98	1,806,140
New Hampshire	2,028,000	0.14	283,920
New Jersey	3,852,000	0.23	885,960
New York	11,759,423	0.16	1,881,508
Ohio	9,323,000	0.83	7,738,090
Pennsylvania	31,193,000	0.41	12,789,130
Rhode Island	658,000	0.24	157,920
Vermont	2,372,000	0.07	166,040
West Virginia	1,182,000	0.66	780,120
Wisconsin	23,412,000	0.69	16,154,280
Total	**151,934,423**		**62,235,998**

Table 3. Annual U.S. Christmas tree production in the southern U.S. (Helmsing, 2004; USDA-ERS, 1990; USDA-NASS, 2002).

State	Sales	Proportion of Trees Sold that are Pines	Estimated Annual Pine Christmas Tree Sales
Alabama	1,200,000	0.93	1,116,000
Arkansas	332,000	NA	NA
Florida	1,056,000	0.40	422,400
Georgia	2,095,000	0.91	1,906,450
Kentucky	1,019,000	1.00	1,019,000
Louisiana[1]	831,098	0.99	822,787
Mississippi	7,611,000	0.99	7,534,890
North Carolina	57,625,000	0.22	12,677,500
Oklahoma	636,000	NA	NA
South Carolina	2,427,000	0.90	2,184,300
Tennessee	2,312,000	0.92	2,127,040
Texas	6,541,000	0.92	6,017,720
Virginia	9,633,000	0.58	5,587,140
Total	**93,318,098**		**41,415,227**

[1]Value estimated based on an average U.S. price of $19 per tree (USDA-NASS, 2002; Helmsing, 2004).

Table 4. Annual U.S. Christmas tree production in the western U.S. (Helmsing, 2004; Mintum pers. comm., 2005; USDA-ERS, 1990; USDA-NASS, 2002).

State	Sales	Proportion of Trees Sold that are Pines	Estimated Annual Pine Christmas Tree Sales
California	12,028,000	0.37	4,450,360
Colorado	398,000	NA	NA
Idaho	862,000	NA	NA
Kansas[1]	552,786	0.90	497,507
Montana	623,000	NA	NA
Nebraska	797,000	0.99	789,030
New Mexico	369,000	NA	NA
North Dakota[1]	38,133	0.69	26,312
Oregon	107,984,000	0.01	1,079,840
Utah	103,000	NA	NA
Washington	26,270,000	0.01	262,700
Wyoming	41,000	NA	NA
Total	**150,065,919**		**7,105,749**

[1]Value estimated based on an average U.S. price of $19 per tree (USDA-NASS, 2002; Helmsing, 2004).

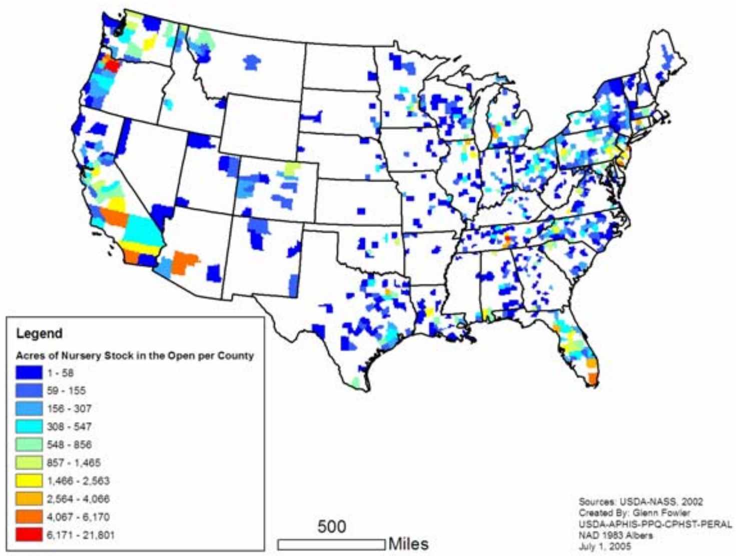

Figure 11. U.S. nursery stock acreage in the open.

Table 5. Annual coniferous evergreen nursery data for selected U.S. states (USDA-NASS, 2004). Average values based on 2000 and 2003 nursery data are reported. Nursery data was reported for operations with annual sales greater than $100,000.

State	**Producers**	**Plants Sold**	**Sales**
Alabama	56	2,104,500	8,236,500
California	123	5,610,000	64,606,500
Connecticut	26	2,843,000	25,080,500
Florida	144	2,649,500	20,389,500
Georgia	47	2,127,000	11,653,500
Illinois	82	665,500	19,063,500
Michigan	79	2,603,500	33,264,000
New Jersey	94	1,550,000	25,726,500
New York	52	530,000	9,866,000
North Carolina	125	1,607,000	19,776,000
Ohio	79	1,578,000	27,509,500
Oregon	161	10,601,500	97,569,500
Pennsylvania	96	1,093,500	27,986,500
South Carolina[1]	37	818,000	4,547,000
Tennessee	93	1,080,000	9,793,000
Texas	47	884,500	8,186,000
Virginia[2]	32	708,000	9,535,000
Washington	39	637,000	7,298,500
TOTAL	**1,412**	**39,690,500**	**430,087,500**

[1]South Carolina only reported data for 2000.
[2]Virginia only reported data for 2003.

Stem attacks by *T. piniperda* can cause tree mortality and a reduction in commodity value due to the introduction of blue stain fungi (CABI, 2004). This type of damage could pose an economic threat to the U.S. softwood timber industry which: 1) produces large quantities of timber, 2) has timber processing mills throughout the country and 3) has annual sales of logs, lumber, pulpwood and veneer valued at nearly 20 billion dollars (LDAF, 2000; Prestemon *et al*., 2005; USDA-USFS, 2001, 2003; USDC, 1999a, 1999b, 1999c) (Figure 12; Tables 6, 7, 8 and 9).

Tomicus piniperda will usually only successfully attack weakened or felled tree stems (CABI, 2004; Morgan *et al*., 2004; Poland *et al*., 2004). Common causes of tree weakening include: 1) late-season fire, 2) drought, 3) storm throw and 4) defoliation (CABI, 2004). If large quantities of brood material are present then beetle populations can reach levels capable of causing substantial economic damage *e.g.* 1.5 million hectares heavily impacted in pine plantations in the Yunnan province, China over 2 decades (Ye, 1991, 1992). Localized regions in Canada have also been affected in a similar manner (Morgan *et al*., 2004; Scarr *et al*., 1999).

Table 6. U.S. 1996 softwood production in thousand cubic feet (MCF) by region (USDA-USFS, 2001).

U.S. Region	Saw Logs	Veneer Logs	Pulpwood	All Products
Northeast and North Central	336,542	3,075	369,044	815,874
South	2,721,782	736,174	2,399,152	6,154,838
West	2,099,934	384,689	82,472	3,065,488
Total	**5,158,258**	**1,123,938**	**2,850,668**	**10,036,200**

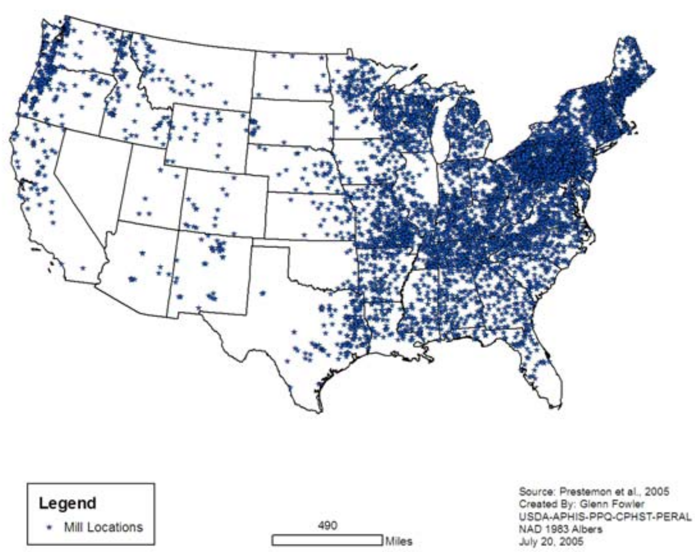

Figure 12. U.S. timber mill locations.

Table 7. Value of selected softwood commodities in the northeastern and north central U.S. that could be affected by *T. piniperda* (LDAF, 2000; USDA-USFS, 2001, 2003; USDC, 1999a, 1999b, 1999c).

State	Softwood Logs and Bolts[1]	Softwood Lumber[1,3]	Softwood Veneer[1,4]	Softwood Pulpwood Production[2]	Total
Connecticut	NA	NA	NA	60,778	60,778
Delaware	NA	NA	NA	1,042,405	1,042,405
District of Colombia	NA	NA	NA	NA	NA
Illinois	NA	NA	NA	85,282	85,282
Indiana	NA	2,985,000	NA	260,529	3,245,529
Iowa	NA	NA	NA	NA	NA
Maine	128,299,000	262,045,000	NA	29,551,781	419,895,781
Maryland	3,210,000	29,220,000	NA	2,144,664	34,574,664
Massachusetts	NA	10,809,000	NA	241,633	11,050,633
Michigan	2,659,000	24,857,000	NA	10,000,351	37,516,351
Minnesota	4,689,000	43,997,000	NA	11,742,430	60,428,430
Missouri	NA	2,891,000	NA	3,225	2,894,225
New Hampshire	5,368,000	110,054,000	NA	5,125,285	120,547,285
New Jersey	NA	NA	NA	119,913	119,913
New York	4,362,000	17,856,000	NA	6,622,404	28,840,404
Ohio	NA	5,406,000	NA	486,798	5,892,798
Pennsylvania	NA	9,254,000	NA	1,518,974	10,772,974
Rhode Island	NA	NA	NA	88,938	88,938
Vermont	NA	NA	NA	4,173,256	4,173,256
West Virginia	NA	6,311,000	NA	1,110,557	7,421,557
Wisconsin	NA	24,224,000	NA	17,698,846	41,922,846
Total	**148,587,000**	**549,909,000**	**NA**	**92,078,047**	**790,574,047**

[1]Values are in 1997 dollars.
[2]Values based on the average 1996 Louisiana southern pine pulpwood price per cord adjusted to 1998 dollars.
[3]Refers to lumber that is not edge worked and not manufactured from purchased lumber (USDC, 1999b).
[4]Includes veneer backed with cloth, paper or another flexible material (USDC, 1999c).

Table 8. Value of selected softwood commodities in the southern U.S. that could be affected by *T. piniperda* (LDAF, 2000; USDA-USFS, 2001, 2003; USDC, 1999a, 1999b, 1999c).

State	Softwood Logs and Bolts[1]	Softwood Lumber[1,3]	Softwood Veneer[1,4]	Softwood Pulpwood Production[2]	Total
Alabama	67,078,000	803,149,000	36,721,000	117,562,990	1,024,510,990
Arkansas	152,623,000	817,759,000	12,627,000	35,409,337	1,018,418,337
Florida	77,317,000	244,798,000	NA	81,277,478	403,392,478
Georgia	96,614,000	998,557,000	52,696,000	119,639,174	1,267,506,174
Kentucky	NA	14,057,000	NA	938,390	14,995,390
Louisiana	107,022,000	412,891,000	33,950,000	64,595,774	618,458,774
Mississippi	271,459,000	937,552,000	28,866,000	58,912,520	1,296,789,520
North Carolina	122,671,000	571,646,000	11,255,000	54,777,797	760,349,797
Oklahoma	NA	129,014,000	NA	8,145,651	137,159,651
South Carolina	38,898,000	532,022,000	NA	63,356,945	634,276,945
Tennessee	NA	6,046,000	NA	12,692,221	18,738,221
Texas	210,876,000	424,550,000	9,607,000	32,336,410	677,369,410
Virginia	10,642,000	234,115,000	6,310,000	31,883,749	282,950,749
Total	**1,155,200,000**	**6,126,156,000**	**192,032,000**	**681,528,435**	**8,154,916,435**

[1]Values are in 1997 dollars.
[2]Values based on the average 1996 Louisiana southern pine pulpwood price per cord adjusted to 1998 dollars.
[3]Refers to lumber that is not edge worked and not manufactured from purchased lumber (USDC, 1999b).
[4]Includes veneer backed with cloth, paper or another flexible material (USDC, 1999c).

Table 9. Value of selected softwood commodities in the western U.S. that could be affected by *T. piniperda* (LDAF, 2000; USDA-USFS, 2001, 2003; USDC, 1999a, 1999b, 1999c).

State	Softwood Logs and Bolts[1]	Softwood Lumber[1,3]	Softwood Veneer[1,4]	Softwood Pulpwood Production[2]	Total
Arizona	NA	45,962,000	NA	339,814	46,301,814
California	154,140,000	1,758,190,000	60,169,000	NA	1,972,499,000
Colorado	NA	35,359,000	NA	NA	35,359,000
Idaho	245,711,000	823,895,000	31,398,000	4,833,801	1,105,837,801
Kansas	NA	NA	NA	NA	NA
Montana	115,308,000	509,193,000	NA	1,182,282	625,683,282
Nebraska	NA	NA	NA	NA	NA
New Mexico	NA	NA	NA	371,569	371,569
Nevada	NA	NA	NA	NA	NA
North Dakota	NA	NA	NA	NA	NA
Oregon	993,860,000	2,418,176,000	392,057,000	2,182,786	3,806,275,786
South Dakota	NA	NA	NA	NA	NA
Utah	NA	13,867,000	NA	NA	13,867,000
Washington	1,331,068,000	1,610,913,000	80,165,000	6,170,894	3,028,316,894
Wyoming	2,008,000	73,182,000	NA	NA	75,190,000
Total	**2,842,095,000**	**7,288,737,000**	**563,789,000**	**15,081,146**	**10,709,702,146**

[1]Values are in 1997 dollars.
[2]Values based on the average 1996 Louisiana southern pine pulpwood price per cord adjusted to 1998 dollars.
[3]Refers to lumber that is not edge worked and not manufactured from purchased lumber (USDC, 1999b).
[4]Includes veneer backed with cloth, paper or another flexible material (USDC, 1999c).

The introduction of *T. piniperda* into the U.S. has resulted in the implementation of quarantines within infested states (CFR, 2003, 2005) (Figure 3). Regulated articles affected by these quarantines include: 1) pine Christmas trees, 2) logs (with bark), 3) lumber (with bark), 4) nursery stock, 5) raw materials for wreaths and garlands and 6) stumps. These quarantines can cause economic losses due to the cost associated with treatments, certification and rejected shipments.

Good stand management practices, *e.g.* sanitation and thinning, can limit brood host material, resulting mortality and economic damage (Morgan *et al*., 2004; Haack and Poland, 2001). This has so far been the case with *T. piniperda* in North America (Haack and Poland, 2001). Despite its rapid spread, *T. piniperda* has caused little economic damage with the exception of localized unmanaged pine plantations in New York (1 stand) and Ontario (Czokajlo *et al*., 1997; Scarr *et al*., 1999).

With regard to potential economic impact on southern U.S. pines, it should be noted that hurricanes and tropical storms could create conditions that are favorable for *T. piniperda* outbreaks. The Atlantic coast hurricane season occurs between June 1 and November 30 (USDC-NOAA, 2004) (Figure 13). These storms can cause large numbers of trees to be blown down (Marsinko *et al*., No Date). If *T. piniperda* were present in the south this type of weather phenomenon could result in large quantities of brood host material becoming available. Storm felled trees can produce large amounts of beetles because the entire tree can be colonized (CABI, 2004). In Europe the combination of poor forest management and storms has led to outbreaks of *T. piniperda* (Nilsson, 1976). However, the economic consequences of these outbreaks were not quantified (CABI, 2004).

Figure 13. Hurricane Ivan (USDC-NOAA, 2004).

The southern U.S. produces 60% of the nation's timber (USDA-USFS, 2003). It produces more timber than any individual country on the planet. Softwood (especially southern pine) forestry is a major source of revenue in the South (Table 8). Over the past 50 years the south has surpassed the western states as the nation's leading producer of softwood timber and pulpwood (USDA-USFS, 2003) (Table 6). Reasons for this include: 1) technological advances in southern pine manufacturing and treatment, 2) short rotation periods and 3) increased demand for strong pulp fiber (Adams, 1995; Helms, 1995; Tesch, 1995; USDA-USFS, 2003; Walker, 1995). This increase in production has resulted in increased investment in southern pine production and advances in stand management and tree genetics (USDA-USFS, 2003). Models forecasting southern timber trends through the year 2040 have predicted: 1) softwood timber prices will increase, 2) this will drive increased softwood timber production and 3) pine plantation area in the south is expected to increase by 67% (USDA-USFS, 2003).

Loblolly pine (*Pinus taeda*) is the most important pine species for timber and pulpwood production in the south and comprises over 50 percent of the pine in this region (UFL, No Date; About Inc., 2005). *Tomicus piniperda* can successfully use loblolly pine for both brood host material and shoot feeding (Eager *et al*., 2004). Other southern pine species that could be affected by *T. piniperda* include: 1) longleaf pine, 2) shortleaf pine and 3) slash pine (USDA-USFS, 1991) (Figure 6).

Given the current and future economic value of southern pine resources and the uncertainty regarding what impact *T. piniperda* will have when and if it reaches the south, it is prudent to protect southern pine resources by the most efficacious means available. Suggested protection methodologies are addressed in the Recommendations section.

E. Risk Element 5: Environmental impact

Impact Categories:

1. Cause impacts on ecosystem processes (*e.g.* increases fire risk due to feeding or disease transmission).
2. Cause impacts on natural community composition (*e.g*., reduce bio-diversity, affect native populations, affect endangered or threatened species).
3. Cause impacts on community structure (*e.g*., change density of a canopy layer, eliminate or create a canopy layer).
4. Have impacts on human health such as disease transmission or production of allergens.
5. Stimulate control programs including toxic chemical pesticides or introduction of a non-indigenous biological control agent.

Rating	Numerical Score	Explanation
High	3	Three or more of the above.
Medium	2	Two of the above.
Low	**1**	**One of the above.**
Nil	0	None of the above.

Rank: Low

Tomicus piniperda is considered a secondary bark beetle that typically attacks only weakened or dead trees and speeds up decomposition (Ciesla, 2001; Morgan *et al*., 2004). Its introduction could result in the implementation of control programs that use insecticides, *e.g.* Dimilin (CABI, 2004; Ciesla, 2001; Långström *et al*., 2001). This confers *T. piniperda* a rank of Low with regard to environmental impact.

As mentioned earlier, *T. piniperda* will probably be able to establish in the south (Haack pers. comm., 2005; Hain pers. comm., 2005). However, the rate and degree of establishment and any resulting environmental damage will probably be lessened by the presence of indigenous bark beetles, *e.g. I. calligraphus*, which compete for brood host material and occupy a similar niche (Haack pers. comm., 2005).

Sound silvicultural practices and the maintenance of vigorous forests have been shown to lessen any environmental impact caused by *T. piniperda* (Morgan *et al*., 2004). The maintenance of healthy forests through thinning and sanitation is already implemented widely in the south in order to minimize *D. frontalis* outbreaks (USDA-USFS, 2003). If introduced, pine tree damage associated with *T. piniperda*, *e.g*. broken shoots on the forest floor and reduced growth, will probably be most apparent in areas that are unmanaged, *e.g*. federal forest lands, and on sites that cannot support healthy tree growth (Morgan *et al*., 2004; USDA-USFS, 2003). This has so far been the case in the northeast and north central U.S. where *T. piniperda* has only caused substantial damage in unmanaged plantations despite its rapid spread and wide distribution (Czokajlo *et al*., 1997; Haack and Poland, 2001; Scarr *et al*., 1999).

F. Cumulative Risk Element Score

Cumulative Risk Element Score	Risk Rating	Risk Score
5-7	Low	1
8-11 (Habitat suitability = 3) + (Host Range = 1) + (Dispersal Potential = 3) + (Economic Impact = 3) + (Environmental Impact = 1) = **11**	**Medium**	**2**
12-15	High	3

Rank: Medium

V. Pathways of Introduction

A. Natural Spread and Human Movement of Infested Commodities in the Regulated Area

Tomicus piniperda was first detected in the U.S. near Cleveland, Ohio in 1992 (Haack and Kucera, 1993). Subsequent surveys conducted that year detected additional infested counties in Illinois, Indiana, Michigan, Ohio, Pennsylvania and New York (Haack and Poland, 2001). As of July 13, 2005 *T. piniperda* has been detected in 14 states, resulting in 473 regulated counties (Haack and Poland, 2001; Heilman *et al*., 2005; NAPIS, 2005; USDA-APHIS, 2005a, 2005b) (Figure 3). Using Cleveland as focal point, this represents an average radial expansion of 429 miles in every direction over 13 years and an average spread rate of 33 miles per year. This estimate errs on the side of caution because *T. piniperda* may have been introduced at more than one location and been present for some time, *e.g.* 1982, prior to its initial discovery (Carter *et al*., 1996; Czokajlo *et al.*, 1997; Haack and Poland, 2001). The observed rate of spread can be attributed to: 1) human movement of infested commodities in the regulated area, 2) wind dispersal, 3) long distance flight and 4) increased survey activities (Barak *et al*., 2000; CFR, 2003; Haack and Poland, 2000; Haack and Poland, 2001). Figure 14 visualizes the projected 10 year distribution of *T. piniperda* at an annual dispersal rate of 33 miles per year assuming no inhibition of movement by abiotic and/or biotic factors. This map represents a potential worst case scenario for *T. piniperda* spread with regulation.

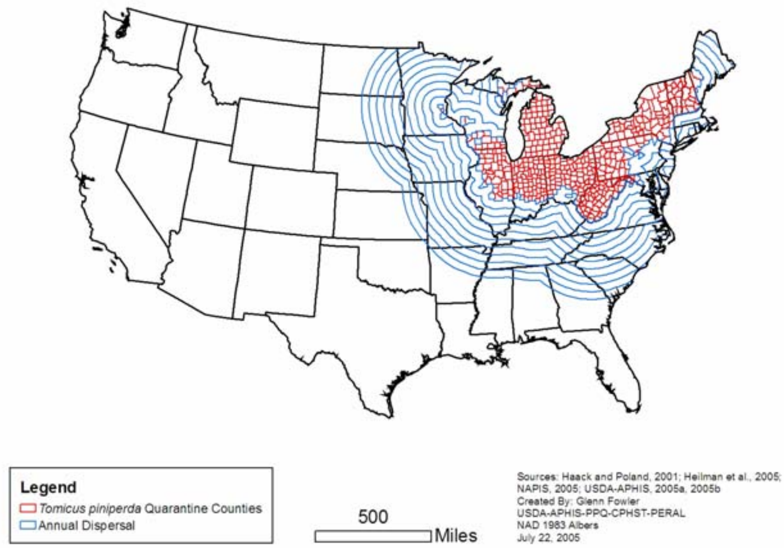

Figure 14. Projected *T. piniperda* 10 year dispersal with regulation assuming no inhibition by abiotic or biotic factors.

Given its documented rate of spread it is probable that *T. piniperda* will continue to move to the east and northeast. What is less certain is how it will spread to the south and west. As mentioned earlier, *T. piniperda* will likely encounter interspecific competition with native bark beetles for brood host material as it moves southward (Haack pers. comm., 2005) (Figures 7 and 8). This combined with good stand management may reduce the rate and degree of *T. piniperda* movement into the southern states (Haack pers. comm., 2005; USDA-USFS, 2003). The western movement of *T. piniperda* may be inhibited by the vertical band of states from North Dakota to central Texas, *i.e.* the Great Plains states, where the pine host forest density is greatly diminished (Wikipedia, 2005) (Figures 4, 5 and 6). The plains are characterized by prairies that harbor large expanses of grasses and few trees. This could reduce the rate of spread by *T. piniperda* since it will become more difficult to locate brood host material and mates due to lack of aggregation pheromones (CABI, 2004; Haack and Kucera, 1993; OHDNR, 2005).

B. Artificial Spread and Pathways of Introduction from the Regulated Area

Tomicus piniperda can readily move in wood materials, *e.g*. dunnage, and is frequently intercepted at U.S. ports (169 times since 1985) (Haack, 2001; Haack and Poland, 2001; PIN, 2005). Currently, the following pine commodities are regulated by USDA-APHIS as potential pathways of *T. piniperda* movement: 1) bark nuggets, 2) barked logs and lumber, 3) Christmas trees, 4) nursery stock, 5) raw pine materials for wreaths and garlands and 6) pine stumps (Haack and Poland, 2001; CFR, 2003, 2005). These articles are regulated during times of the year when they would likely be infested by *T. piniperda*, *e.g.* November to June for logs (Haack and Poland, 2001, Poland *et al*., 2002). As *T.*

piniperda continues to spread, it will be necessary to adjust the times of regulation to match climates in lower latitudes (Haack *et al*., 1998; Poland *et al*., 2002).

The regulatory program cannot stop the natural spread of *T. piniperda*. However, it does appear to be preventing long distance human mediated dispersal, *e.g.* movement of *T. piniperda* over 1 or more states in a year (Figure 3). Time series analysis indicates that *T. piniperda* range expansion has been relatively uniform from the initial areas of establishment. This indicates natural spread and human movement of infested commodities in the regulated area (Haack and Poland 2001; Heilman *et al*., 2005).

However, exceptions to this trend have occurred. In 1999 *T. piniperda* was detected in 2 counties in Vermont and 1 county in New Hampshire, approximately 148 miles away from the nearest infested U.S. county (Figure 3). In 2004, it was detected in 1 Wisconsin county approximately 40 miles away from the nearest infested county. In 2005, *T. piniperda* was detected in 3 Minnesota counties approximately 65 miles away from the nearest infested county. Aside from a failure of the quarantine, these exceptions could have occurred because of: 1) separate introductions and/or 2) increased surveys (Haack and Poland, 2001).

The rate of *T. piniperda* spread via human mediated transport mechanisms, in the event of deregulation, will depend on a number of factors including: 1) *T. piniperda* commodity infestation rate, 2) commodity shipping distance, 3) method of commodity disposal, *e.g.* chipping, 4) volume of commodity imported and 5) time of importation. There is a large degree of variability with regard to the risk of *T. piniperda* introduction by pathway, regional commodity production and shipping intensity. For example, deregulation of the Christmas tree or nursery pathways could facilitate the movement of *T. piniperda* throughout the U.S. in a single year (Koelling *et al*., 1992; Monrovia Nursery, 2005). However, the likelihood of introduction via the Christmas tree pathway maybe low because pest management practices can limit *T. piniperda* populations in plantations (Haack and Poland, 2001). Deregulation of the pulpwood pathway could increase the southern rate of spread to 60 to 75 miles per year due to mill pulpwood purchase radii (Johnson and Steppleton, 2000; Timber Mart-South, 2001). Due to this variability, we suggest that the rate of human mediated spread in the event of *T. piniperda* deregulation be estimated with specific risk assessments for each region and pathway (see Recommendations section).

VI. U.S. Regional Differences in Ecological Suitability to *T. piniperda*

The U.S. Forest Service divides the continental U.S. into 8 regions (Figure 15) (USDA-USFS, 2005). The northeastern and north central states are covered by region R9 (eastern). The south is covered by region R8. The western states are divided into 6 regions (R1-R6). Differences between the northeast, north central, south and west with regard to *T. piniperda* risk are discussed below.

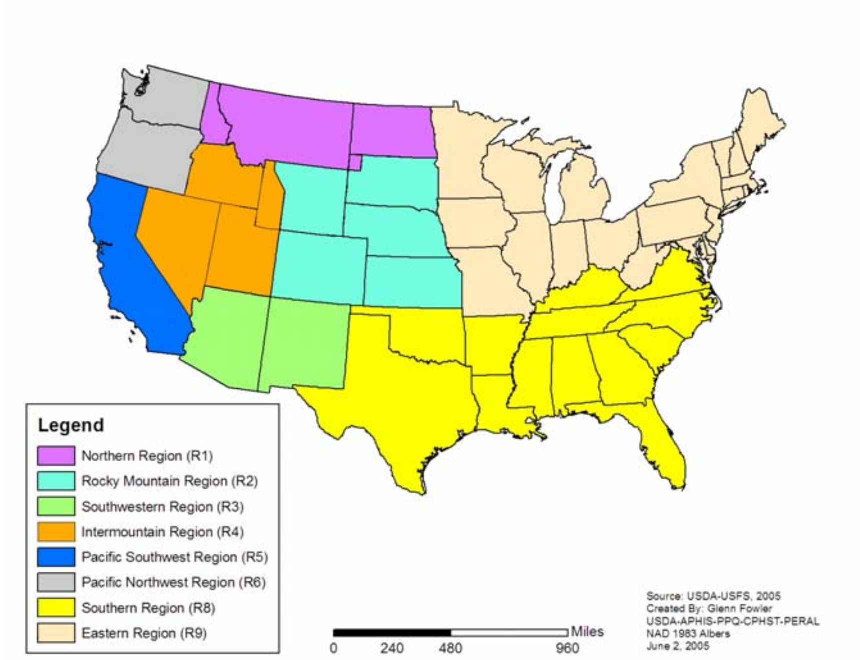

Figure 15. USFS Regions.

A. Northeast and North Central

Compared to the west and south, the northeastern and north central U.S. has a lower density and distribution of pine hosts (Figures 4, 5 and 6). Consequently, the softwood timber industry in the northeast and north central U.S. is not as large as the south or west (Tables 6, 7, 8 and 9). Also, white pine is one of the major forest types in the northeast and north central U.S. (Figure 6). White pine, a soft pine, is less suitable as a host for *T. piniperda* than the hard pines, *e.g.* Scots pine, with regard to host preference and reproduction (CABI, 2004; Price *et al*., 1998; Ryall and Smith, 2000). For example, *T. piniperda* fecundity and offspring production was substantially lower on white pine than on jack, red or Scots pine (all hard pines) (Price *et al*., 1998; Ryall and Smith, 2000). This difference was significant with regard to fecundity between white pine and Scots pine and offspring production between white pine and red pine (Ryall and Smith, 2000). In addition to good stand management, this may be one of the reasons why *T. piniperda* has only caused minimal damage in the northeast and north central U.S. as compared to its impact in Europe and China (CABI, 2004; Czokajlo *et al*., 1997; Haack and Poland, 2001; Lånsgström *et al*., 2001; Lieutier *et al*., 2003). These factors indicate that the northeast and north central U.S. may be at lower risk for impact to pine timberland resources by *T. piniperda* than the south and west (see below) (Tables 10, 11 and 12).

The northeast and north central U.S. has a substantial Christmas tree and nursery industry (Figures 10 and 11; Tables 2 and 5) (Helmsing, 2004; USDA-NASS, 2002; 2004). These industries have so far not experienced noticeable crop damage from *T. piniperda* (Haack and Poland, 2001). This may be due to good stand management practices, *e.g.* sanitation and integrated pest management, which limit brood host material, shoot damage and beetle population levels (Morgan *et al*., 2004; Haack and Poland, 2001; McCullough and Sadof, 1998). However, the northeast and north central U.S. Christmas tree and nursery industry have been economically impacted by quarantines on the movement of regulated articles (CFR, 2003, 2005; Haack and Poland, 2001; Riessen, 1997). These quarantines cause economic losses due to the costs associated with treatments, certification and rejected shipments.

Table 10. Risk assessment table for *T. piniperda* in the northeastern and north central U.S.

Risk Element	Rating	Numerical Score	Explanation
Habitat Suitability	High	3	*Tomicus piniperda* could establish in USDA plant hardiness zones 3-6 (NAPPFAST, 2005; USDA-USFS, 1991; Ye, 1994)
Host Range	Low	1	Attacks multiple species in the genus *Pinus* (CABI, 2004)
Dispersal Potential	High	3	Can move long distances via human, innate and wind dispersal mechanisms and has high reproductive potential (Barak *et al.,* 2000; Haack and Poland, 2000, 2001; Sauvard, 1993; USDA-APHIS, 1993)
Economic Impact	Low	1	Has caused quarantines (CFR, 2005)
Environmental Impact	Low	1	Has stimulated chemical control programs (CFR, 2005; McCullough and Sadof, 1998)
Cumulative Risk	**Medium**	**9**	

B. South

The southern U.S. has a high density of pines distributed in a uniform manner across the entire region (Figures 4, 5 and 6). The major pine forest types in the south are: 1) loblolly, 2) shortleaf, 3) slash and 4) longleaf (USDA-USFS, 1991) (Figure 6). All of these forest types are hard pines (Diploxylon), the preferred hosts of *T. piniperda* (CABI, 2004; Price *et al*., 1998). At a minimum, 5 southern pine species (loblolly, longleaf, shortleaf, slash and Virginia) are suitable brood hosts and 2 (loblolly and shortleaf) can serve as shoot-feeding hosts (Eager *et al*., 2004). Loblolly is the most important species for timber and pulpwood production in the south and comprises over 50 percent of the pine in this region (UFL, No Date; About Inc., 2005).

The south is the leading producer of softwood timber in the U.S. with annual sales of approximately 8 billion dollars in timber, lumber, pulpwood and veneer (Tables 6 and 8) (LDAF, 2000; USDC 1999a, 1999b, 1999c; USDA-USFS, 2001, 2003). In addition, the south is frequently struck by hurricanes and tropical storms which could produce large quantities of brood host material for *T. piniperda* (CABI, 2004; Nilsson, 1976; USDC-NOAA, 2004).

The south also has a substantial Christmas tree and nursery industry (Figures 10 and 11; Tables 3 and 5) (Helmsing, 2004; USDA-NASS, 2002; 2004). *Tomicus piniperda* could impact these industries by reducing crop aesthetic value as a result of shoot damage (Haack and Kucera, 1993, McCullough and Sadof, 1998; OHDNR, 2005) (Figure 9). In addition, quarantines associated with the introduction of *T. piniperda* could cause economic losses due to the costs associated with treatments, certification and rejected shipments (CFR, 2003, 2005; Haack and Poland, 2001).

These characteristics indicate that the south is potentially at greater risk from *T. piniperda* than the northeast and north central U.S. As mentioned earlier, good stand management and interspecific competition may reduce the impact of *T. piniperda* in the south. However it is prudent to protect these resources given the uncertainty and potential risks associated with its introduction.

Table 11. Risk assessment table for *T. piniperda* in the southern U.S.

Risk Element	Rating	Numerical Score	Explanation
Habitat Suitability	High	3	Could establish in USDA plant hardiness zones 6-9 (NAPPFAST, 2005; USDA-USFS, 1991; Ye, 1994)
Host Range	Low	1	Attacks multiple species in the genus *Pinus* (CABI, 2004)
Dispersal Potential	High	3	Can be carried long distances via human, innate and wind dispersal mechanisms and has high reproductive potential (Barak *et al.,* 2000; Haack and Poland, 2000, 2001; Sauvard, 1993; USDA-APHIS, 1993)
Economic Impact	High	3	Could cause pine growth reductions, tree mortality, aesthetic damage, and quarantines (CABI, 2004; CFR, 2005; Långström and Hellqvist, 1991; Ye, 1991, 1992)
Environmental Impact	Low	1	Could stimulate chemical and/or biological control programs (CFR, 2005; Haack and Poland, 2001; Lieutier, 2003; McCullough and Sadof, 1998; OHDNR, 2005; Schroeder, 1996)
Cumulative Risk	**Medium**	**11**	

C. West

Overall, the west produces less softwood timber than the southeast and more than the northeast and north central U.S. (Table 6). However the total value of western softwood timber products analyzed in this assessment is the highest in the U.S., *i.e.* approximately 11 billion dollars annually in logs, lumber, veneer and pulp products (Table 9). This may be due, in part, to the large quantity of high priced softwood timber, *e.g.* Douglas fir, harvested in western states, *e.g.* Oregon and Washington, and rising timber prices due to lower investments in forestry (Helms, 1995; Tesch, 1995; Skog and Risbrudt, 1982; USDA-USFS, 2003).

Parts of the west have a higher density of pines than the south or northeast and north central U.S. but they are not as uniformly distributed as in the southern U.S. (Figures 4, 5 and 6). Western states with the highest pine densities, and therefore the highest risk from *T. piniperda*, are: 1) California, 2) Idaho, 3) Montana, 4) Oregon and 5) Washington. Western states with comparatively moderate pine densities are: 1) Arizona, 2) Colorado, 3) New Mexico, 4) South Dakota (southwestern portion), 5) Utah and 6) Wyoming.

Western states with comparatively low pine densities are: 1) Kansas, 2) Nebraska, 3) Nevada, 4) North Dakota and 5) the majority of South Dakota.

The main pine forest types in the west are: 1) lodgepole, 2) ponderosa and 3) western white (Figure 6). The majority of the pine area is comprised of lodgepole and ponderosa (USDA-USFS, 1991). Both of these are hard pines and consequently are preferred hosts of *T. piniperda* (CABI, 2004; Price *et al*., 1998). *Tomicus pinip*erda can use both lodgepole and ponderosa pine as brood and shoot feeding material (Eager *et al*., 2004).

Also, western pine stands are often stressed by droughts and forest fires that could predispose them to *T. piniperda* attack (CABI, 2004; Swetnam, 2001). Drought is thought to be one of the factors that facilitated large scale mortality of Yunnan pines in China from *T. piniperda* (Ye, 1991, 1992). The lack water would result in reduced resin production which the trees need to defend against *T. piniperda* stem attack (Ye, 1991).

Like the northeastern, north central and southern U.S., the west has a substantial Christmas tree and nursery industry (Figures 10 and 11; Tables 4 and 5) (Helmsing, 2004; USDA-NASS, 2002; 2004). *Tomicus piniperda* could impact these industries by reducing crop aesthetic value as a result of shoot damage (Haack and Kucera, 1993, McCullough and Sadof, 1998; OHDNR, 2005) (Figure 9). In addition, quarantines associated with the introduction of *T. piniperda* could cause economic losses due to the costs associated with treatments, certification and rejected shipments (CFR, 2003, 2005; Haack and Poland, 2001).

Due to these characteristics, we categorize the west in a position of greater risk from *T. piniperda* compared to the northeast and north central U.S. and equal risk compared to the south. It should be noted that, unlike the south, the natural spread of *T. piniperda* westward may be mitigated by a lack of concentrated host material in the Great Plains states (OHDNR, 2005; USDA-USFS, 1991; Wikipedia, 2005). This may form a natural barrier that slows or prevents the westward movement of *T. piniperda* by natural processes, *e.g.* flight. Consequently, the most probable method of introduction would be human transport. Therefore, the identification and mitigation of high risk pathways could substantially lower the risk posed by *T. piniperda* to the western states as compared to the south where it would be easier to establish via natural spread.

Table 12. Risk assessment table for *T. piniperda* in the western U.S.

Risk Element	Rating	Numerical Score	Explanation
Habitat Suitability	High	3	Could establish in USDA plant hardiness zones 3-8 (NAPPFAST, 2005; USDA-USFS, 1991; Ye, 1994)
Host Range	Low	1	Attacks multiple species in the genus *Pinus* (CABI, 2004)
Dispersal Potential	High	3	Can be carried long distances via human, innate and wind dispersal mechanisms and has high reproductive potential (Barak *et al.,* 2000; Haack and Poland, 2000, 2001; Sauvard, 1993; USDA-APHIS, 1993)
Economic Impact	High	3	Could cause pine growth reductions, tree mortality, aesthetic damage, and quarantines (CABI, 2004; CFR, 2005; Långström and Hellqvist, 1991; Ye, 1991, 1992)
Environmental Impact	Low	1	Could stimulate chemical and/or biological control programs (CFR, 2005; Haack and Poland, 2001; Lieutier, 2003; McCullough and Sadof, 1998; OHDNR, 2005; Schroeder, 1996)
Cumulative Risk	**Medium**	**11**	

VII. Potential Effects of Deregulation by U.S. Region

As mentioned above, *T. piniperda* appears to be spreading primarily by natural means and human movement of infested commodities in the regulated area and the regulatory program seems to be preventing its rapid movement across long distances. The deregulation of articles that move *T. piniperda* through human transport could facilitate rapid long distance movement and subsequent establishment throughout much of the U.S. (Figures 4, 5 and 6). The precise nature of the risk posed by specific pathways to each U.S. region should be addressed in specific risk assessments (see Recommendations section). Some potential impacts of total deregulation by U.S. region are discussed below.

A. Northeast and North Central

Total deregulation of *T. piniperda* would probably have the least impact regarding risk of introduction in the northeastern and north central states, *i.e.* USFS region 9 (Figure 15). This is because the majority of this region is already infested (Figure 3). A recent risk assessment by Caton and Spears (2005) predicted that the likelihood of *T. piniperda* introduction into Maine via white pine materials was low compared to the current rate of spread. This indicates that deregulation would not measurably increase *T. piniperda*'s rate of dispersal and establishment given the current rate of spread and limited geographic area left in the northeast and north central U.S. that is not infested.

B. South

As mentioned earlier, the natural spread of *T. piniperda* into the south may be slowed by interspecific competition and good stand management (Haack pers. comm., 2005; Morgan *et al.*, 2004). Deregulation could increase the rate of *T. piniperda* introduction and spread in the southern states.

Deregulation of the timber pathways, *e.g.* pulpwood, could result in a series of sequential introductions moving from north to south, *e.g.* movement from Maryland to Virginia, rather than long distance introductions, *e.g.* Michigan to Florida. This is because mills typically import wood from nearby sources, *e.g.* within state or from one state away and buying radii of 60 to 75 miles (Marsinko *et al*., No Date; Johnson and Steppleton, 2000; Timber Mart-South, 2001). A large number of pulp and timber mills operate in the south (USDA-USFS, 2003) (Figures 16 and 17) and the main pine type processed in the south is loblolly (About Inc., 2005; UFL, No Date). Loblolly pine is a preferred host of *T. piniperda* and can be utilized for both brood and shoot feeding (CABI, 2004; Eager *et al*., 2004; Price *et al*., 1998). Also, *T. piniperda* will disperse from mills where timber is stored and associated tree damage is often highest in the vicinity of mills (Poland *et al*., 2000; Långström and Hellqvist, 1991). These facts indicate that deregulation of pine timber could place southern pine resources at risk from *T. piniperda* because timber mills could serve as reservoirs for introduction, development and spread.

Deregulation of the Christmas tree and nursery pathways could cause long distance introductions in the south because they are often shipped throughout the U.S. (Koelling *et al*., 1992; Monrovia Nursery, 2005). *Tomicus piniperda* can probably complete its development on harvested Christmas trees and consequently they could provide a pathway for introduction (Haack *et al*., 2001). However, the risk of introduction via the Christmas tree pathway maybe low because stand management practices can limit *T. piniperda* populations in plantations (Haack and Poland, 2001). Pine nursery stock is used as a landscape plant and could also serve a pathway for introduction (Monrovia Nursery, 2005).

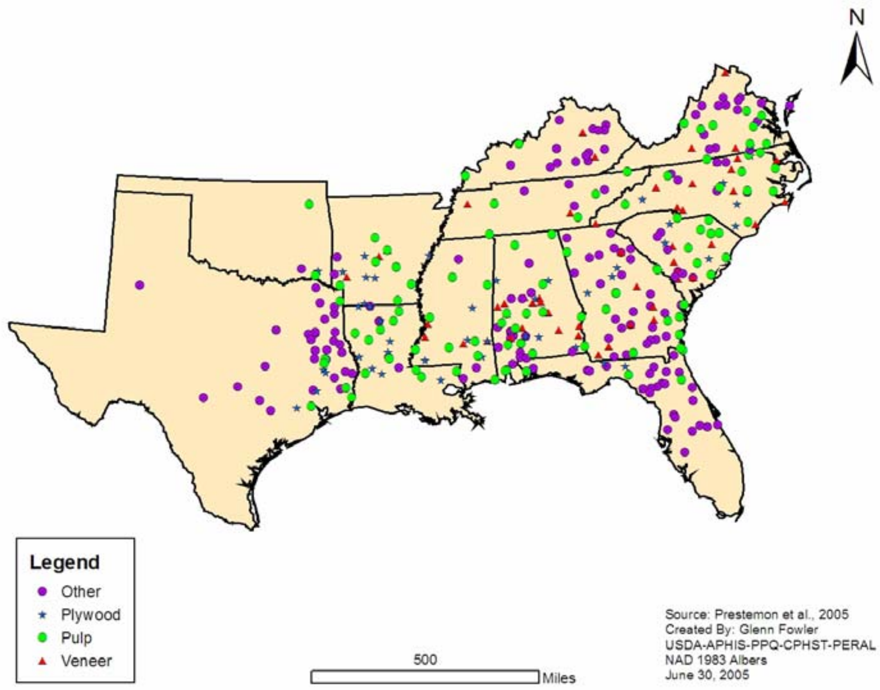

Figure 16. Southern pulp and miscellaneous mills.

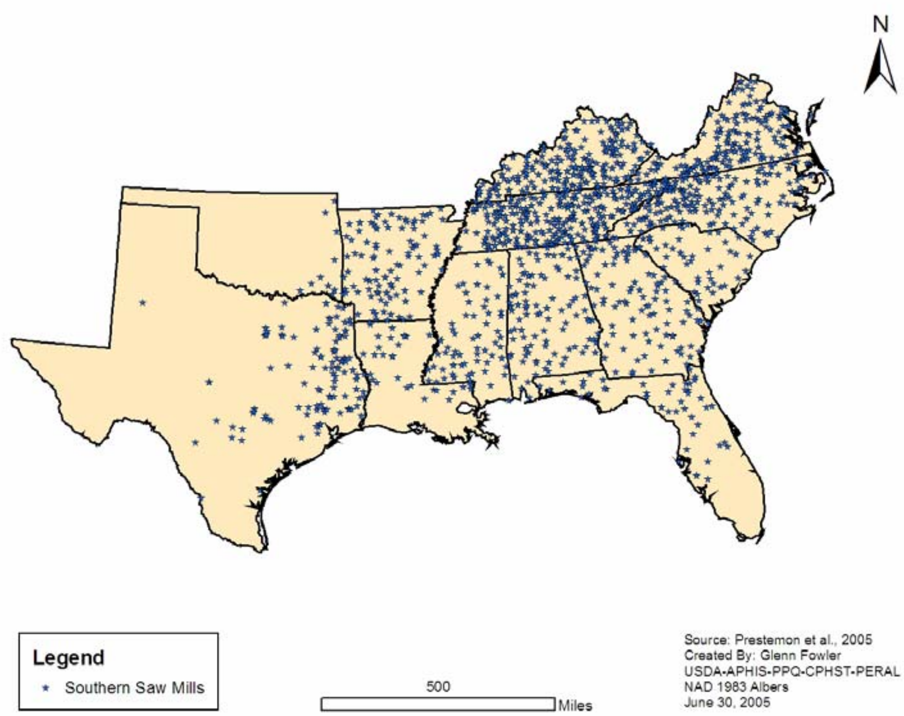

Figure 17. Southern saw mills.

C. West

The west has concentrated areas of suitable hosts for *T. piniperda* that are often stressed by fires and drought and could be at risk for establishment (CABI, 2004; Swetnam, 2001) (Figures 4, 5 and 6). However, it may also be the easiest region to protect from *T. piniperda* introduction with regulatory methods. This is because a lack of concentrated host material in the plains states and a lack of effective aggregation pheromones may mitigate the natural movement of *T. piniperda* to at risk western pine resources (Haack and Kucera, 1993; USDA-USFS, 1991; Wikipedia, 2005). Consequently, efficacious regulation of at risk articles may prevent *T. piniperda* from reaching the west and total deregulation for this region is not recommended.

VIII. Control Options

A variety of methods are available to control *T. piniperda*. The methods listed here are not intended to be a comprehensive list but rather to provide examples of control methodologies.

A. **Biological Control:** The following organisms have been shown to control *T. piniperda* but may need approval from APHIS and/or state regulatory agencies for importation into and within the United States.

   1. *Atanycolus initiator* (Hymenoptera: Braconidae) (Urano and Hijii, 1991)

   2. *Beauveria bassiana* (Anamorphic Fungi**)** (CABI, 2004; Niu and Lu, 1992)

   3. *Canningia tomici* sp. n. (Microsporidia: Unkifayonidae) (Kohlmayr *et al*., 2003)

   4. *Hypophloeus longulus* (Coleoptera: Tenebrionidae) (Pishchik, 1980)

   5. *Rhaphidia ophiopsis* (Coleoptera: Raphidiidae) (Pishchik, 1979)

   6. *Rhizopahgous depressus* (Coleoptera: Rhizophagidae) (Schroeder, 1996)

   7. *Thanasimus formicarius* (Coleoptera: Cleridae) (Haack and Poland, 2001; Schroeder, 1996)

B. **Chemical Control:** The following chemical control measures and associated insecticides are recommended for controlling *T. piniperda.* Listing of these chemical control methods does not imply that they are either efficacious or labeled for this use in the United States, or specific states within the United States.

1. Decamethrin: Effective for cut logs (Carle and Jamin, 1980).

2. Deltamethrin: Effective as a dip for seedlings or a spray in forests and timber yards (Glowacka *et al*., 1991).

3. Dimilin: Effective in forest settings (Långström *et al*., 2001).

4. Methyl Bromide: Effective for bark, chips, logs, lumber and stumps (CFR, 2003).

C. **Physical Control:**

1. Strip Barking: Provides limited protection for stored logs (Dehlen and Långström, 1977).

D. **Regulatory Control:** The following regulatory steps are recommended.

1. Quarantines: Regulated articles currently include: 1) pine bark, 2) Christmas trees, 3) logs and lumber with bark, 4) nursery stock, 5) raw materials for garlands and wreaths and 6) stumps (CFR, 2003, 2005). The quarantines are implemented at times of the year when *T. piniperda* is likely to be infesting a given regulated article, *e.g.* logs (Haack and Poland, 2001).

2. Surveys: These are typically conducted using baited traps and trap logs (Haack and Poland, 2001; Poland *et al*., 2003). Predictive forecast systems, *e.g.* NAPPFAST, could be used to increase their efficacy.

3. Compliance Agreements: This methodology has been used by pine Christmas tree growers, mills and nursery growers for *T. piniperda* to expedite the shipment of regulated articles (Haack and Poland, 2001; Maine Forest Service, 2002; McCullough and Sadof, 1998).

E. **Silvicultural Control**:

1. Sanitation: This removes *T. piniperda* brood host material and reduces beetle populations (Morgan *et al*., 2004).

2. Thinning: This increases stand vigor and resistance to *T. piniperda* stem attack (Amezaga, 1997; Morgan *et al*., 2004).

3. Trap Logs: Effective in Christmas tree or natural stands (McCullough and Sadof, 1998; Triggianai, 1983). This method operates by attracting beetles to the trap logs during the brood period and then destroying them before emergence.

4. Economic Damage Levels: Setting acceptable limits on damage can be used to determine efficacious treatment regimes (Berryman, 1986). For example, less than 100 *T. piniperda* shoot attacks per tree results in minimal growth loss (Långström and Hellqvist, 1991). Consequently, no treatment would be required below this level.

IX. Conclusions

This risk assessment evaluated the overall risk to the U.S. associated with *T. piniperda.* The beetle scored medium with regard to cumulative risk. It scored high with regard to habitat suitability, dispersal potential and economic impact. *Tomicus piniperda* scored low with regard to host range due to its preference for species in the genus *Pinus* (CABI, 2004). The environmental impact was scored as low for the U.S. based on the historical and biological information regarding *T. piniperda's* impact in natural forest settings (Ciesla, 2001; Haack and Poland, 2001; Morgan *et al*., 2004). These scores indicate that *T. piniperda* could pose a potential economic threat to the U.S. Christmas tree, forestry and nursery industries.

Climate will probably not limit the distribution of *T. piniperda* in the U.S. (Ye, 1994). Consequently, its projected area of colonization in the U.S. will probably depend on the distribution of pines. Pines are found throughout the U.S. with the highest concentrations in the south, west and northeast and north central states, respectively (Figures 4, 5 and 6).

Regions of the U.S. were evaluated for susceptibility and associated impact from *T. piniperda*. Factors considered included: 1) host type, 2) host density and 3) potential economic impacts to the forestry, Christmas tree and nursery industries (Figures 4, 5, 6, 10 and 11; Tables 2, 3, 4, 5, 6, 7, 8 and 9). We scored the south and west as being at greater risk from *T. piniperda* as compared to the northeast and north central U.S. (Tables 10, 11 and 12).

The southern U.S. has a concentrated distribution of pines that are uniformly distributed (Figures 4, 5 and 6). The major planted pine species in the south is loblolly, a suitable *T. piniperda* host for both brood and shoot feeding (Eager *et al*., 2004). The estimated annual value of southern logs, pulpwood, timber and veneer is valued at over 8 billion dollars (Johnson and Steppleton, 2000; USDA-USFS, 2003; USDC, 1999a, 1999b, 1999c) (Table 8). The south is the world's largest softwood timber producer and its output is projected to increase (USDA-USFS, 2003). In addition, the south is often struck by tropical storms and hurricanes that could produce substantial brood host material for *T. piniperda* (CABI, 2004; Marsinko *et al*., No Date). These characteristics indicate that southern pine resources may be at substantial economic risk from *T. piniperda*.

However, there is uncertainty regarding the spread rate and degree of impact *T. piniperda* will have on southern pine resources due to interspecific competition with native bark beetles and stand vigor (Haack pers. comm., 2005; Haack and Poland, 2001; Morgan *et al*., 2004). Given the potential consequences of *T. piniperda* introduction, it is recommended that southern pine resources be protected by regulatory means that are precise and economically expedient until more is known regarding its ability to impact the south. Central questions that need to be addressed include: 1) can *T. piniperda* displace indigenous bark beetles, 2) will *T. piniperda* cause minimal forest damage in the southern U.S. as it does in the northeast and north central U.S. or will it become a major forest pest as observed in China and Europe and 3) how will *T. piniperda*'s biology, *e.g.* overwintering behavior and flight patterns, change as it moves into lower latitudes.

Tomicus piniperda can spread through natural or artificial means. Natural spread mechanisms include: 1) flight and 2) wind dispersal (Barak *et al*., 2000; Haack and Poland, 2000). Artificial, *i.e.* human mediated, pathways of *T. piniperda* movement include: 1) bark nuggets, 2) barked logs and lumber, 3) Christmas trees, 4) Nursery stock, 5) raw pine materials for wreaths and garlands and 6) pine stumps (Haack and Poland, 2001; CFR, 2003, 2005).

Currently, *T. piniperda* appears to be spreading through: 1) natural means, *e.g.* flight, and 2) human movement of infested commodities in the regulated area at a maximum average estimated rate of 33 miles per year (Haack and Poland, 2001; Heilman *et al*., 2005; NAPIS, 2005; USDA-APHIS, 2005a, 2005b). We concluded this because the beetle has not generally moved great distances, *e.g.* across one or more states, in a single year.

Tomicus piniperda will probably be able to continue spreading to the east and northeast as long as host material is available regardless of regulation. Its natural spread to the south may be mitigated by interspecific competition from native bark beetles and good stand management (Haack pers. comm., 2005; Haack and Poland, 2001: Morgan *et al*., 2004). Its natural spread west may be mitigated by a lack of concentrated host material in the plains states and the absence of aggregation pheromones (CABI, 2004; Haack and Kucera, 1993; OHDNR, 2005; Wikipedia, 2005).

The effect of deregulation on the rate of *T. piniperda* spread throughout the U.S. will depend on a variety of factors including: 1) *T. piniperda* commodity infestation rate, 2) commodity shipping distance, 3) method of commodity disposal, *e.g.* chipping, 4) volume of commodity imported and 5) time of importation. There is a large degree of variability with regard to the risk of *T. piniperda* introduction by pathway, regional commodity production and shipping intensity. For example, deregulation of the

Christmas tree or nursery pathways could facilitate the movement of *T. piniperda* throughout the U.S. in a single year (Koelling *et al*., 1992; Monrovia Nursery, 2005). However, the likelihood of introduction via the Christmas tree pathway maybe low because pest management practices can limit *T. piniperda* populations in plantations (Haack and Poland, 2001). Deregulation of the pulpwood pathway could increase the southern rate of spread to 60 to 75 miles per year due to mill pulpwood purchase radii (Johnson and Steppleton, 2000; Timber Mart-South, 2001). Due to this variability, we suggest that the rate of human mediated spread in the event of *T. piniperda* deregulation be estimated with specific risk assessments for each region and pathway.

The fact that *T. piniperda* has not generally moved across one or more states in a given year indicates that the regulatory program is preventing its long distance movement via artificial means, *e.g.* pine nursery tree or timber shipments. Therefore the regulatory program should be maintained until more is known regarding the impact of *T. piniperda* on other regions of the country. However, consideration could be given to exploring the practicality of adjusting the regulatory program: 1) to reflect regional differences in *T. piniperda* flight period, brood biology and overwintering habits (Haack *et al*., 1998; Poland *et al*., 2002) and 2) to reflect the variation in risk among regions with regard to different pathways. These steps could: 1) provide more efficacious protection due to a targeted and expeditious use of resources and 2) reduce economic costs associated with quarantines. It is acknowledged that while giving relief in various regards to different regions of the country, these adjustments could increase the complexity of the *T. piniperda* regulatory program nationwide and pose new challenges. Suggestions on how to improve the precision of the regulatory program are provided in the Recommendations section.

X. Recommendations

A. Quantitative Risk Assessment of *T. piniperda* by U.S. Region and Pathway(s)

We recommend conducting a series of comprehensive quantitative risk assessments characterizing the risk posed by *T. piniperda* to each USFS region by the regulated pathways. These types of assessments can identify the pathways that pose the greatest and least risk for introduction. Regulation based on this type of analysis should increase the efficacy of *T. piniperda* control measures and reduce economic losses resulting from unnecessary quarantines. For example, the southeast may be at greater risk from the pulpwood timber pathway than the Pacific Northwest because mills will sometimes import this commodity from nearby states *e.g.* West Virginia (Johnson and Steppleton, 2002; Timber Mart-South, 2001). However, the Christmas tree and nursery stock pathway could pose a risk to all regions because they are often shipped throughout the U.S. (Koelling *et al*., 1992; Monrovia Nursery, 2005).

Secondly, quantitative risk assessments can elucidate whether or not regulation appreciably reduces the likelihood of *T. piniperda* introduction to an area given the natural rate of spread. This type of information can be used to determine if regulation of a given pathway is necessary. For example, Caton and Spears' (2005) risk assessment concerning *T. piniperda* movement on white pine materials from the regulated area into Maine concluded that the likelihood of introduction via this pathway was low. Consequently, regulation of white pine materials would not appreciably slow the timing of *T. piniperda* introduction and was therefore unnecessary.

Also, associated sensitivity analyses can identify what parameters have the greatest impact on the introduction of *T. piniperda* by pathway, *e.g.* number of sawmills in a given region, population size buying Christmas trees or volume of timber imported. This type of information is useful in implementing efficacious methods to mitigate the pathway. Once a comprehensive model has been generated it could be used to rapidly model the other regions by simply modifying the data inputs. This methodology has been used in other assessments and associated bilateral negotiations, *e.g.* Karnal bunt (Fowler *et al*., 2005), to model the risk posed to different countries by inputting their respective trade data.

Given the potential consequences and uncertainties associated with *T. piniperda* introduction, we consider a systematic quantitative approach that estimates the risks by pathway and geographic region to be the safest, most precise and scientifically sound method for formulating regulatory policy.

B. Temporally Adjust the Quarantine Months to Match *T. piniperda* Distribution

A number of researchers have advocated modifying the months when *T. piniperda* is regulated to accommodate changes in spring flight and fall shoot departure by latitude (Haack *et al*., 1998; Poland *et al*., 2002). Temporally adjusting the regulations to match *T. piniperda's* biology should increase the efficacy of artificial spread mitigation.

To facilitate temporal adjustments of the quarantine, geospatial models have been constructed that identify when and where *T. piniperda* regulation should be implemented based on historical climatological data (Haack *et al*., 1998; Poland *et al*., 2002). The NAPPFAST predictive modeling system may be of substantial use in this endeavor. It can rapidly generate historical probability maps for North America using 10, 20 or 30 year data (Figures 18 and 19). In addition, NAPPFAST has 10 day forecast capability that could be of use in predicting *T. piniperda* flight times and subsequent surveys.

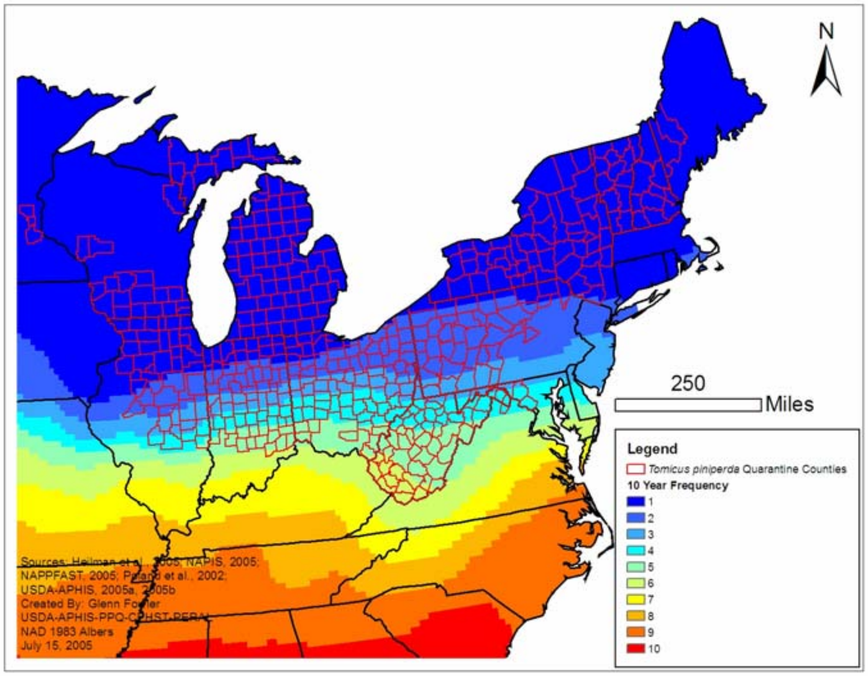

Figure 18. Ten year frequency map (1995-2004) visualizing areas where *T. piniperda* emergence is likely between February 1-7 because of 2 days with temperatures greater than or equal to 12°C (Poland *et al*., 2002).

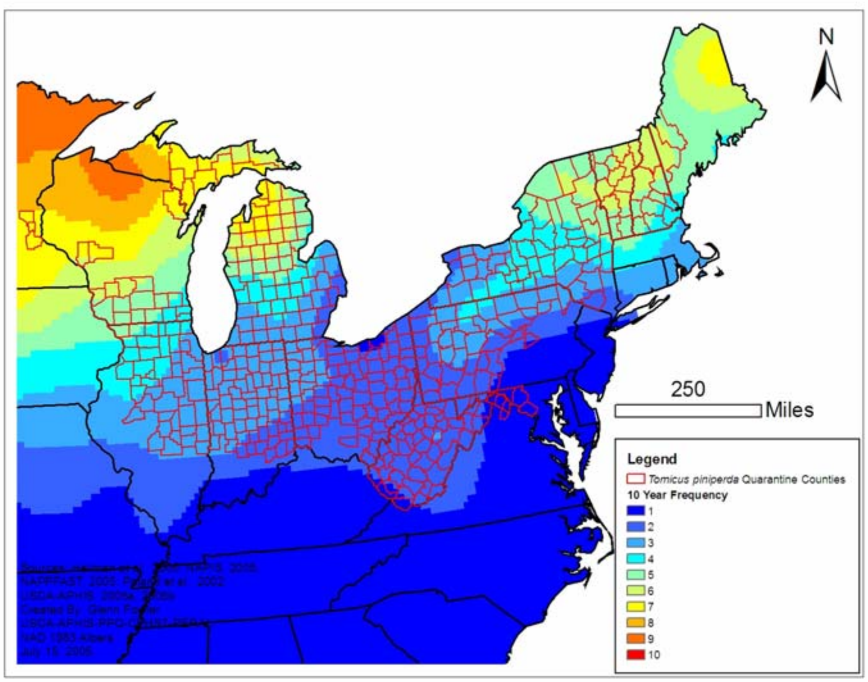

Figure 19. Ten year frequency map (1995-2004) visualizing areas where *T. piniperda* shoot departure is likely between October 1-7 because of 2 days with temperatures less than or equal to 0°C (Poland *et al*., 2002).

XI. Future Research Needs

A. Elucidate the Nature of the Interspecific Competitive Interactions between *T. piniperda* and Native Bark Beetles

Research should be conducted elucidating the nature of the interaction between *T. piniperda* and the native southern bark beetles. Research areas could include: 1) can *T. piniperda* displace native species, 2) what effect(s) does interspecific competition have on *T. piniperda* reproduction, survival and host location and 3) do *D. frontalis* winter flight patterns reduce the early host colonization advantage that *T. piniperda* usually has over other bark beetles?

This type of research will help elucidate the degree of risk posed to the south by *T. piniperda*. West Virginia may be an optimal research site because *T. piniperda* and the major indigenous bark beetles, *i.e. D. frontalis, D. terebans, I. avulses, I. calligraphus* and *I. grandicollis* are currently present in that state (CABI, 2004).

B. Elucidate how *T. piniperda* Biology Changes as it Moves into Lower Latitudes

Changes in *T. piniperda* biology as it moves south into warmer climates should be studied in order to ascertain the potential damage that could be caused by the beetle in these areas. It is likely that *T. piniperda's* lifecycle will become accelerated as it encounters warmer temperatures and milder winters in the lower latitudes (Ye, 1991). Potential changes in *T. piniperda's* biology as it moves south include: 1) earlier, more frequent and longer flight periods, 2) a higher frequency of sister broods and 3) longer shoot feeding periods and higher associated shoot damage (Haack *et al*., 1998; Långström, 1980; Poland *et al.,* 2002; Ye, 1991). Research topics that need to be addressed as *T. piniperda* moves into lower latitudes include: 1) how will its overwintering behavior change (Haack *et al*., 1998; Poland *et al*., 2002) and 2) will it remain univoltine (Poland and Haack, 2000)?

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